THE

USEFUL ARTS

AND

MANUFACTURES OF GREAT BRITAIN.

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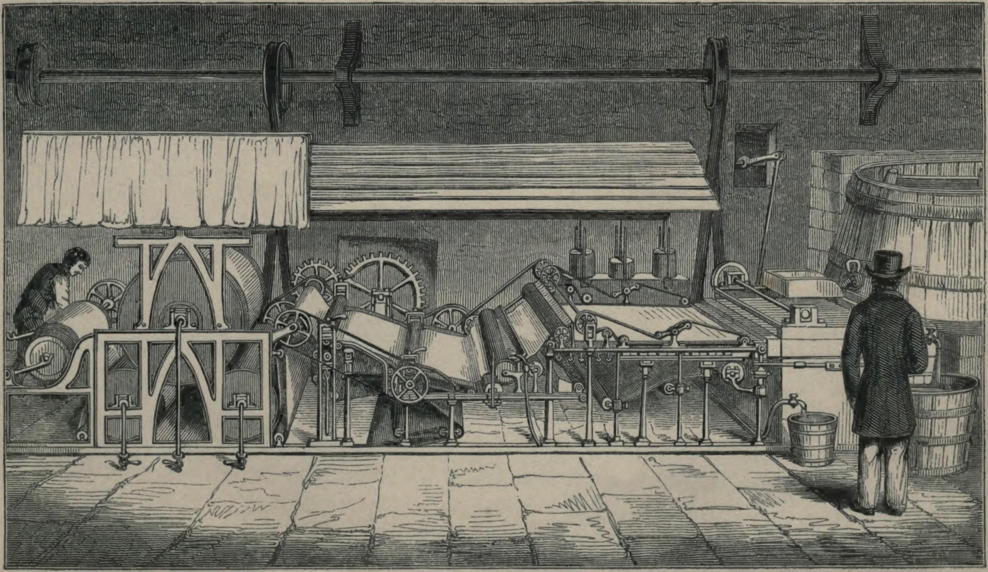


PAPER-MAKING MACHINE.

THE

MANUFACTURE OF PAPER.

NEXT to the invention of printing, there is not, perhaps, a more valuable or important discovery than that of the fabrication of paper from linen rags. By this discovery, the comforts and advantages of life have been greatly increased, knowledge has been widely diffused, and the holy Scriptures, once confined to the libraries of the wealthy or the learned, have been placed within the reach of the humblest individuals.

The substitutes for paper, among the nations of antiquity, were the prepared skins of animals, and the inner bark of trees; while, for public records and national edicts, the most enduring substances, such as tables of stone or of brass, were commonly employed. Thus the law delivered to Moses on Mount Sinai was engraven on tables of stone (Exod. xxxi. 18), as a lasting record of the Divine will; and there is reason to believe that the "book" mentioned in the seventeenth chapter of Exodus was composed of skins, prepared for writing on.

But there was also, at a very remote period, a certain species of paper manufactured by the Egyptians from the *papyrus*, or *paper reed;* a plant growing freely on the banks of the river Nile in Egypt, or in marshy places near that stream; and supposed to be identical with a plant still common in many rivers of the East, called by botanists *Cyperus papyrus*. Under Egyptian culture, the papyrus sprang up to the height of fifteen or twenty feet; but, as now seen, it never exceeds ten feet. The stem is bulky, gradually tapering to a point, and bearing at the top a very elegant tuft of long loose filaments with small seedy flowerets. The inner bark of the stem was the portion used in making paper, and this was prepared

in the following manner:—Thin plates of bark were taken from the middle part of the stem, (which always afforded the best paper,) and were laid singly, but close to each other, on a hard smooth table; other pieces of the same size were then laid across them at right angles; the whole was moistened with the water of the Nile, which was said to possess a gummy or glutinous quality, capable of making the plates of bark adhere together; pressure being likewise applied for a certain number of hours. The sheets of paper thus obtained, were rubbed and polished with smooth stone, or with a solid glass hemisphere, and dried in the sun. When there was any difficulty in making the sheets adhere together, a little fine paste made of wheaten flour was used to facilitate the process. Sometimes the sheets were formed of great length, but none of the specimens that have reached our times are very broad. Belzoni had a papyrus in his possession twenty-three feet long, by one-and-a-half broad. The glutinous quality of the waters of the Nile has been denied by the traveller Bruce, who says:—"I made several pieces of this paper, both in Abyssinia and in Egypt; and it appears to me, that the sugar or sweetness with which the whole juice of the plant is impregnated is the matter that causes the adhesion of these strips together, and that the water only serves to dissolve this, and put it perfectly in solution."

The papyrus is undoubtedly the most ancient description of paper of which we have any record; but there is still existing among the Chinese a manufacture of paper, peculiar to themselves, and probably of very early date. The inner rind of a tree, resembling our mulberry tree, is the material employed for this purpose; and the process of converting it into paper is as follows:—The smaller branches are cut into lengths not exceeding three feet, and boiled in an alkaline ley, for the purpose of loosening the bark; this is then peeled off, and dried for future use. When a sufficient quantity of bark has been laid up, it is

again softened in water for three or four days, and the outer parts scraped off as useless: the rest is boiled in clear ley, which is kept strongly agitated all the time, until the bark has become tender, and separable into distinct fibres; it is then placed in a pan or sieve, and washed in a running stream; being, at the same time, worked with the hands until it becomes a delicate and soft pulp. For the finer sorts of paper, the pulp receives a second washing in a linen bag; it is then spread out on a smooth table, and beaten with a wooden mallet until it is extremely fine. Thus prepared, it is put into a tub with a slimy infusion of rice, and a root called *oreni;* there it is stirred until the ingredients are properly blended; it is then removed to a large vessel, in order to admit of moulds being dipped into it. These moulds are made of bulrushes cut in narrow strips, and mounted in a frame; as the paper is moulded, the sheets are placed on a table covered with a double mat. The sheets are laid one on the other, with a small piece of reed between every leaf, which, standing out a little way, serves afterwards to lift them up leaf by leaf. Every heap is covered by a board and weights, to press out the water; on the following day, the sheets are lifted singly by means of the projecting reeds, and are placed on a plank to be dried in the sun. This paper is so delicate that only one side can be written on; but the Chinese sometimes double the sheets, and glue them together so neatly that they appear to be a single leaf.

It was sometime during the twelfth century that an invention became known in Europe, which soon superseded the ordinary writing materials then in use, and also formed an important step towards our present manufacture: this was no other than the making of paper from cotton; at first the raw cotton itself; afterwards, old worn-out cotton cloth. This sort of paper was of Eastern invention, and was first introduced into Europe by the Arabs, who established a manufactory

of paper in Spain. So long as this manufacture was conducted by them, the paper was of a very coarse and inferior quality, in consequence of their employing only mortars, and hand or horse mills, for reducing the cotton to a pulp; but some Christian labourers having obtained the management of the paper-mills at Toledo and Valencia, greatly improved the processes of the manufacture. Cotton paper became general about the end of the twelfth and beginning of the thirteenth centuries, but in the fourteenth century it was almost entirely superseded by the happy discovery of making paper from linen rags.

Important as was the discovery of linen as a material for making paper, there is much uncertainty as to the time when it was first tried, and the country to which the honour of the invention is due. It is not at all improbable that the discovery was an accidental one. In countries where flax was plentiful, it could hardly happen but that linen rags should sometimes get mixed with the cotton ones employed in the manufacture; and if, from such accidental mixture, the quality of the paper was improved, it followed as a matter of course, that the intelligent manufacturer would increase the quantity of linen rags, until, at last, he would find the benefit of using them solely, and thus would discard cotton altogether.

According to the best authorities, there were no books made of linen paper, either in France or Italy, before the year 1270. But in the fourteenth century the use of this kind of paper became general. In 1380, a Genoese ship, which was driven ashore on the English coast, was found to contain twenty-two bales of writing-paper. The oldest German paper-mill was erected at Nuremberg in 1390. There are English manuscripts on linen paper as early as 1340; but it is generally believed that the manufacture was not introduced into this country till the year 1588, at which time a German named Spielman, jeweller to Queen Elizabeth, erected a paper-mill at Dartford in

Kent. But it is now known that long before that period one John Tate of Hertford produced paper of a superior kind used in the *Bartholomeus* of Wynkyn de Worde, which has been described as "one of the most splendid productions of the early British press." But it is equally well known that for a lengthened period our principal supply of fine paper for writing and printing was obtained from abroad: it is indeed only within the last century that this manufacture has become a flourishing one in England. At the present time, however, the state of affairs is so completely changed, that we not only make an abundant supply for our own use, but export paper to a considerable amount.

The extent of our manufacture of this article at one time led to serious apprehensions that the supply of linen rags would fail to meet the growing demand. Under this idea some ingenious individuals set themselves to discover other substances, which, in case of necessity, might be used as substitutes. In the library of the British Museum, and also of the Society for the Encouragement of Arts, may be seen a book written in German, containing upwards of sixty specimens of paper made of different materials, the result of experiments made at the period in question. The book was written by M. Schäffers,* who was so enthusiastic in his pursuit of substances for this purpose, that it would seem "the whole world assumed to him the character of one vast mass of latent material for paper." His eagerness in this matter was so well known, that persons were continually bringing to him the most dissimilar substances, with the inquiry, "Can you make this into paper?" In this way he was led to convert into paper the bark of the willow, the beech, the aspen, the hawthorn, the lime, and the mulberry; also the down of the catkins of the black poplar, the silky down of the asclepias, the tendrils of the vine, the

* Sämtliche Papierversuche von Jacob Christian Schäffers, Prediger zu Regensburg. *Regensburg*, 1772.

stalks of nettle, mugwort, dyer's weed, and the common thistle. The bark and stalk of common bryony, and of burdock, the leaves of the cat's-tail or reed-mace, the slender stalks of the clematis, the fibrous stem of the upright lily, and those of the willow-herb, were all likewise employed for the same purpose. He even made paper of such unpromising materials as cabbage-stalks, different kinds of moss, wood-shavings, and saw-dust. He made an excellent paper from potatoes, smooth and soft to the touch, and almost resembling parchment in tenacity. He even produced a good and cheap paper from fir-cones, to which he was led by the habit of a bird (probably the cross-bill) of tearing to pieces the scales of the cone, until a substance resembling tow was produced.

Besides all these substances paper has been made from straw, from rice, from the stalks of the mallow, the bine of hops, the roots of liquorice, and the husks of Indian corn.

All these experiments are now rendered unnecessary by a valuable discovery of modern chemistry, that of *chlorine.* The bleaching properties of chlorine are so extremely powerful that many of the varieties of coloured linen may by its means be restored to their original whiteness, and thus rendered a proper material for paper. Useless manuscripts, and many kinds of waste paper, may also be completely bleached, and prepared for use a second time. Thus the same material may be employed many times in succession, and every description of material of linen fabric may be put to its utmost use.

MODERN MANUFACTURE OF PAPER.

There is not a more signal instance of the advantage of improved machinery in increasing the supply, and diminishing the cost of an article, than is afforded by paper. Processes which were formerly uncertain and tedious are now executed with precision and expedition. Those which depended upon the

state of the weather, and were consequently during the winter months retarded many weeks, or inefficiently executed, are now completed in the most perfect manner in a very few minutes.

PAPER MILL.

The manufacture of paper is conducted in a paper-mill, and, as abundance of pure water is required for its use, this mill is generally situated on the banks of a considerable stream. Where the stream is of sufficient power, it is sometimes employed to turn a large wheel, which transmits motion to the machinery; but where fuel is cheap, steam power is frequently employed.

The linen rags (with, in some cases, a large admixture of cotton rags) employed in the paper manufacture of this country, are collected in large

quantities at home; but a large supply is also obtained from abroad. This article is imported from Germany, Italy, Sicily, and Hungary, to the amount of about 5,000 tons every year; the value of which is reckoned at from 21*l.* to 22*l.* per ton, freight included. The rags are sent to this country in closely packed bags of about four hundredweight each, and are marked according to the respective qualities of the rag.

It has been remarked that these varieties of rag afford some criterion of the habits and state of comfort of the people from whom they are obtained. The rags of this country are generally clean, and require but little washing; while the Sicilian rags are so foul as to need washing in lime before they are fit for the foreign market. Most of the rags from the north of Europe consist of linen; they are dark in colour, coarse in texture, and plainly indicate how inferior must be the garments of the people to those worn by the humblest persons in our own highly favoured land.

In France, Holland, Belgium, Spain, and Portugal, the exportation of rags is forbidden under severe penalties, lest their own long established factories should suffer from the want of them. Of late years our cotton manufactories have abundantly supplied the paper-maker with an article formerly considered worthless, namely, the cotton waste, and sweepings of the cotton-mills, which, being properly cleaned and bleached, furnish materials for making printing-paper of tolerable quality.

When the rags are brought to the mill, the first thing is to form them into heaps according to their qualities; this is done by women. They are then conveyed in baskets to the rag-house, where another set of women, and sometimes children, called *rag-cutters,* receive them. Each of the women stands at a table, the upper surface of which consists of iron-wire cloth, beneath which is a drawer. A knife or scythe is fixed in the centre of the table, in

RAG-CUTTERS AT WORK.

nearly a vertical position; the woman is placed so as to have the back of the blade opposite to her, while on her right hand, on the floor, is a large wooden box with many divisions. She examines the rags, opens seams, removes dirt, pins, needles, buttons, or other substances which might injure the machinery, or damage the quality of the paper, and then cuts the rags into pieces, not exceeding four inches square, by drawing them across the edge of the knife or scythe. She then throws them into the different divisions of the box according to their quality. During the cutting of the rags, much of the dirt, sand, &c., passes through the wire-cloth into the drawer, which is occasionally cleaned out. Each woman can cut about three quarters of a hundredweight of home rags, or a hundred and a half of foreign rags, in the day of ten working hours. Foreign rags are generally much heavier and stronger than those collected in Scotland and England. The wages of the women average from tenpence to a shilling a day.

After this process, the rags undergo another careful examination by women called *over-lookers,* or *over-haulers,* whose duty it is to see that the work is properly performed, and that no extraneous substance is allowed to remain in the rags. Much of the value and beauty of the paper depends on the careful examination of the rags at this period; for a solid body being present, would in the after stages be ground up with the rags, and be diffused in minute particles over the surface of the paper. The necessity for this careful examination and selection, has prevented the general introduction of several ingenious and powerful machines which of late years have been proposed for cutting the rags.

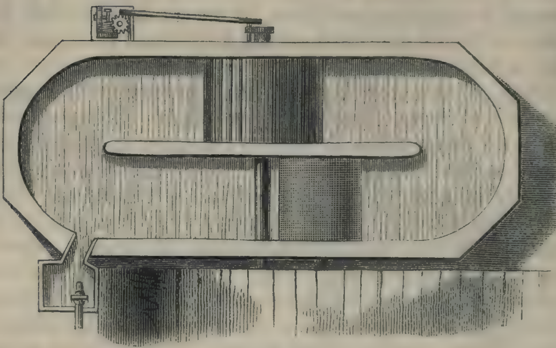
The next process is to place the rags in the *dusting machine,* which is a large cylindrical frame, covered with iron wire-cloth. A part of the circumference opens to admit the rags, of which about one hundred-weight are introduced at a time. On the axis of the interior are a number of spokes, each about a foot long, fixed transversely, which pass through the rags when the machine revolves, and further shake out the particles of dust which may still adhere to them. This machine is sometimes used in the first instance, before the rags are cut, and it thus contributes to render the duties of the rag-cutters less unpleasant and unwholesome.

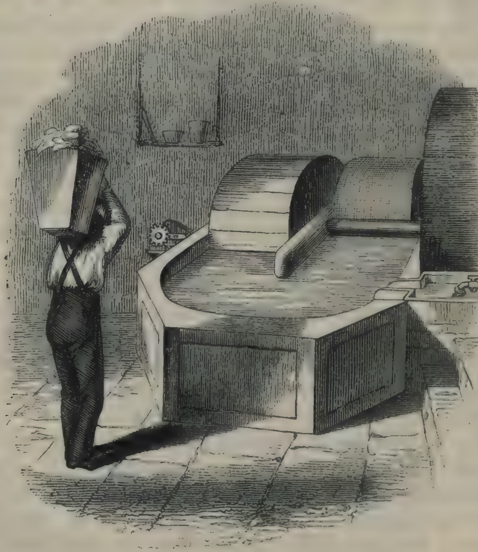
The rags are next boiled in an alkaline ley, made more or less strong according as the rags are more or less coloured; the object being to get rid of the remaining dirt, and some of the colouring matter. The proportion is from four to ten pounds of carbonate of soda, with one-third quick lime to the hundredweight of material: in this the rags are boiled eight hours, more or less, according to their quality; when they are allowed to cool gradually, because in being rapidly cooled they are found to take up again some of the colouring matter they had parted with. When the rags are removed from the boiler, they are either

stored in wooden chests for use, or are at once conveyed to the engine-house, there to be reduced to pulp. This is one of the most important processes of the mill, and requires all its power.

The *engines* for washing and grinding the rags consist of large vats or cisterns of an oblong form, rounded at the angles: they are made of strong wood, lined with lead or copper, or they are constructed wholly of cast-iron: each engine is about ten feet long, four-and-a-half wide, and two deep, and will contain about a hundredweight of rags. Each engine has a partition down the middle in the direction of its length, but not extending quite to either end: this partition is also covered with metal sheeting. The cylinder which washes or grinds the rags is fixed firmly on a shaft, which extends across the vat, and is made to revolve by means of a pinion fixed to its extremity. This cylinder, technically called the *roll*, is of wood, about two feet in diameter, and two feet in length. Round the circumference are firmly fixed bars or teeth of steel, parallel to the axis or spindle. Immediately below the roll is a block of wood of the same length, but of less breadth than its diameter. The upper surface of this block or *plate*, as it is called, follows the curvature of the cylinder, and is provided with a number of teeth, so adjusted as to present a series of cutting edges to the teeth of the revolving cylinder: these opposed series of teeth are not in contact, but may be brought very near together, or removed to a considerable distance, by adjusting the height of the roll; for the elevation and depression of which, provision is made on the outside of the vat.

The engine is provided with water from a small cistern at hand, which is kept constantly full from a pipe, and which is furnished with a strainer of hair or wire, to prevent any impurities from entering. When a due supply of water and of rags has been introduced into the engine, the roll is set in motion,





WASHING AND GRINDING ENGINES.

having been first elevated to its greatest distance from the plate. By the motion of the roll the water is thrown into a current, and the rags are dragged between the teeth of the roll and those of the plate, and then thrown upwards over a rise in the engine, which on the side next the roll forms a segment of a circle, and then descends over a gradual declivity to the flat bottom of the vat. The water and rags are by these means kept continually revolving; the roll is lowered gradually nearer to the plate, and the rags are first thoroughly cleansed, then cut, torn, and chopped to pieces, until at last they are reduced to a uniform pulp.

The first action being to wash the rags thoroughly, it is necessary to get rid of the dirty water, sand, &c. before the rags are reduced to pulp. For this purpose, a certain part of the engine is provided with a false perforated bottom, communicating with a cock, which is left open during the first half-hour of the washing; and as a stream of clear water is constantly flowing into the engine, all extraneous matters are thus drained off.

The action of the cylinder upon the rags is so violent that both water and rags would be thrown out, if left uncovered. An inverted wooden box is therefore placed with one side resting on the edge of the engine, and the other upon the central division. The two ends are closed with frames, or strainers, covered with hair or wire-cloth, sloping outwards; beyond these are wooden frames, which form the two outer ends of the case; the box is also furnished with a bottom and a ledge, except where the cylinder rises up into it. Now this arrangement is to allow the foul water to drain off through the strainers of the box, while every particle of the rags is preserved.

During the first half hour, while the cock remains open, the engine consumes about a hogshead of water per minute, after which a much less quantity is required, in consequence of the rags becoming pulpy and occupying more space: towards the conclusion

of the washing process, the water which passes through the wire-cloth does not amount to one-twentieth of the quantity required at first. After the continued action of the engine during three or four hours, the rags have parted with all their impurities and assumed a somewhat pulpy consistency. In this state they are called *stuff*. When the operation of washing is considered complete, a valve which fits into the bottom of the engine is opened, and the stuff allowed to flow down a pipe into the bleaching-house, where it is received into a draining chest, and left for a time for the water to flow off.

The material used for bleaching is the gas *chlorine*, so called from the circumstance of its being of a *greenish* colour (the Greek word for green being *chloros*); or, the gas is more conveniently used in combination with lime, the chloride of lime being a solid substance, and forming a solution with water. Chlorine exerts a powerful action on organic substances, destroying vegetable colours, and corroding the very fibre of which these substances are composed; it is, moreover, very injurious when taken into the lungs; hence it requires to be used with much caution. The coarse and coloured rags which are imported from abroad would not make white paper but for this powerful agent, by which they are effectually bleached; but white rags are now to be obtained at so cheap a rate that some manufacturers dispense altogether with bleaching. They thus not only get rid of a substance which is often used injuriously, but are enabled to produce a much more durable article.

Bleaching, however, enters into the arrangements of most manufacturers, and it is therefore necessary to describe the process. The bleaching-house is a long apartment, with a passage and a railroad down the middle; the sides are occupied with stone chests, about three feet deep; each is furnished with a false bottom, pierced with a number of small holes, and

under this is a valve, which can be opened at pleasure, to allow the contents to escape into a large tank, which extends under the chests the whole length of the room. By the side of each chest is a small pump, for raising liquor from the tank into the chest.

The stuff being properly drained is transferred to a large box, which is moved along the railroad to supply the chests. About one hundredweight of stuff is placed in each, to which is added from six to eight pounds of chloride of lime in solution with about twelve gallons of water. The chest is then nearly filled up from the tank, which contains a weak solution of the same salt. The stuff is stirred frequently, that the bleaching may go on properly; for the upper layer, being exposed to air and light, is often properly bleached, before the under layers are much affected.

In about twenty-four hours the liquor is drained off; the stuff is lifted into the railway-box, before noticed, and removed to an hydraulic press, where whatever is left of the solution is pressed out and allowed to flow into the tanks. The materials are now greatly reduced in bulk: indeed, the changes which the substances are made to undergo in form, in bulk, in colour, and in texture, are in this, as in many other branches of manufacture, very striking. As respects change of bulk, the following curious calculation is given in the article "Paper" in the Encyclopædia Britannica.

	Cubic feet.
1 cwt. of linen rags, cut, but not pressed, occupy a space of about	5½
When in the washing engine, in process of washing	46
When drained of all the water that will flow out	25½
When pressed by the hydraulic press	7½

The action of the hydraulic press not only lightens the labour of raising the stuff to the higher stories of the engine-house, but also facilitates the process of washing out the chloride of lime, every particle of which it is of the utmost consequence to remove.

The washing is but a repetition of the process as performed in the first engine; it is carried on for about an hour, when the stuff, being in a state half way between rags and paper, is called *half stuff.* It is then let down to the beating-engine, which differs from the washing-engine only in the roll having a greater number of teeth, and being made to revolve with greater velocity. Here it is beaten until, by the continued action of the roll upon the plate during about five hours, the stuff becomes moderately warm, and is, as it were, combed out into short fibres. It is now ready to be made into paper, and is let down into a large reservoir called a chest, in the *vat-house,* as it is called when the paper is made by hand, and the *machine house* when produced by machinery.

The buildings and machinery of a paper-mill require to be of a very solid and substantial kind, in consequence of the tremor produced by the great velocity of the wheels. The roll of a washing-engine revolves at the rate of 120 revolutions per minute; it is furnished with about 40 teeth, each of which passes 14 teeth of the plate, producing 67,000 cuts in a minute, with a grating, growling sound, of a very disagreeable character. In the beating-engine, where the teeth are more numerous and the revolutions more rapid, the noise produced is a coarse musical humming, which may be heard at a great distance from the mill. In the latter the cuts sometimes amount to 200,000 per minute, a velocity which alone enables the manufacturer to convert rags into pulp in so short a time as the extensive demand for paper now requires. The power required to keep each roll moving the stuff when it is tolerably near the plate, is equal to about that of five horses.

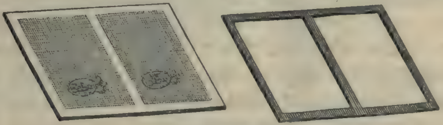
MAKING PAPER BY HAND.

In some of the older establishments, as well as in the modern, for the finer descriptions of writing-paper, and

where it is desired to preserve the water-mark, paper still continues to be made in single sheets. The process, which is a very interesting one, consists essentially in receiving the pulp into moulds, then getting rid of the water, and by pressing and sizing, and other operations, producing the smooth and beautiful surface which we recognise in a sheet of writing-paper.

The pulp having been properly prepared, is received into a chest in the vat-house, from which the vat is supplied. The vat is a stone vessel, about six feet square, and four feet deep. The pulp being heavier than water, would sink were it not kept constantly stirred by means of a little revolving wheel about twelve inches in diameter, called *a hog*. A steam pipe passes through the vat to keep the contents warm; but in some cases a small stove is employed. The upper part of the vat is made to slope inwards, and is also railed in to prevent the stuff from running over.

The moulds into which the pulp is received, and where, in fact, it becomes a sheet of paper, are of



PAPER MOULDS.

two kinds, *laid* and *wove*. A laid mould consists of a neat frame of mahogany, with wooden bars running across it, at the distance of about an inch and a half from each other. Across these are *laid* a number of wires, to the amount of fifteen or twenty to the inch. A strong raised wire laid along each of the cross bars, interlaces the other wires, and this gives to laid paper its ribbed appearance. A *wove* mould is similarly made, the only difference being that its surface is covered with wire-cloth, *wove* for the purpose, and containing from forty-eight to sixty-four wires in an inch, varied according to the fineness of the paper,

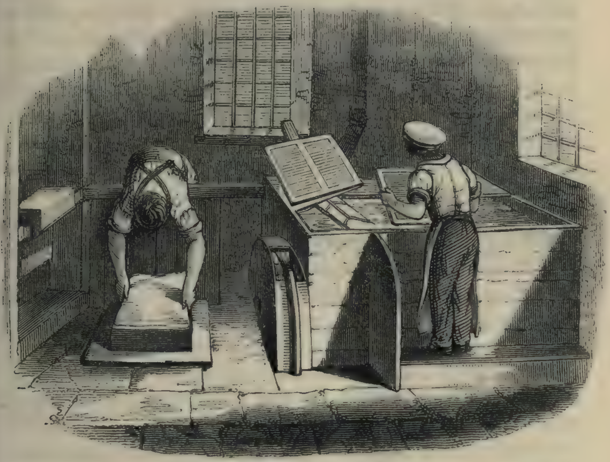
and the nature of the pulp. The water-mark is produced by wires bent to the shape of the letter or device required, and sewed to the surface of the mould; its effect is to make the paper thinner in those places.* Both moulds are furnished with a *deckle*, or moveable raised edging, which the vat-man always holds in his hand; it is made to fit exactly all round the edge of the mould, and prevents the pulp from flowing over and leaving a rough edge. By means of this instrument the water edge is produced, which being different to the edge produced by any other means, is generally adopted in the paper used for bank notes. Moulds of the size of the note are used, so that each note has the water edge all round, and thus forgery is rendered more difficult.

In making paper by hand, two men are required at each vat; one is called the *vat-man*, and the other the *coucher*. The vat-man is furnished with two moulds, in order to save time; for while the coucher is taking off a sheet from one mould, the vat-man is filling the other. The vat-man stands at one side of the vat, and the coucher opposite to him, at the corner of the side on the vat-man's left. Between them, along the top of the vat, is a board, called a *bridge*, with copper fillets fastened lengthwise upon it, along which the vat-man slides the mould to the coucher.

The stuff in the vat being properly prepared, that is, sufficiently diluted with water, sufficiently warm, and by means of the active exertions of the little hog, equally diffused throughout the water,—the vat-man takes one of the moulds, furnished with its deckle, by the middle of the short sides, and plunges

* The old makers adopted a variety of devices to distinguish their papers. The water-marks on the paper used by Caxton and other early printers, consisted of an ox-head and star, a collared dog's head, a crown, a shield, a jug, &c. A head with a fool's cap and bells, was the origin of the name *foolscap paper*: *post* paper was so called from its bearing the mark of a horn, which was formerly carried by the postman, and blown to announce his arrival.

it obliquely four or five inches into the vat, when, taking up a quantity of the stuff upon it, he raises it to a level, shaking it so as to distribute the stuff and



MAKING PAPER BY HAND.

form a uniform fabric; while doing so, he gradually raises the mould; the water escapes through the wires, and the superfluous stuff escapes over the sides of the frame. This operation, however simple it may appear, is a very delicate one, and requires a long apprenticeship to perform successfully. The stuff requires to be equally distributed over the surface of the mould, and the mould to be held perfectly level when taken out of the vat, otherwise the sheet would be imperfect, or thicker in one part than in another.

As soon as a portion of the water has drained off, the vat-man raises the deckle, and slides the mould, with the wet sheet upon it, along the bridge to the coucher, who places it, for a few seconds, in an inclined position, in order that more of the water

may drain off. Meanwhile, he places a piece of felt or blanketing upon a wooden plank, and then taking the mould, presses the face of it upon the felt, which receives and takes off the sheet from the mould, although still in a very wet state. The mould is returned to the vat-man, who, by this time, has filled his second mould, and is ready to give a second sheet to the coucher. The process is continued by piling up upon each other, alternately, a sheet and a piece of felt, till from four to eight quires of paper, according to its size, have been formed, and this quantity is called *a post*. Such is the celerity of the process, that, for many sorts of paper, the two men make upwards of twenty posts in a day.

The post being completed it is loaded with a heavy plank, and conveyed to a press where more water is squeezed out. When removed from the press, the paper can be handled; the sheets are separated from the felts, and placed together in a *pack*, while the felts are returned to the coucher and vat-man, who proceed to form a new post.

As the paper in its early stage retains the impression of the wire, &c. of the mould, and also of the surface of the felt, the object of the subsequent operations is to smooth it and to soften the grain; this is accomplished by repeated pressings and foldings. A number of *packs* being collected together, they are all put into another press, where a portion of the remaining water is forced out in drops; care is required in this pressing, for the sheets are apt to stick together. After this the sheets are separated one by one and turned; that is, the surface of every sheet is exposed to a new one, and then they are again pressed. This pressing and parting are repeated according as the quality of the paper seems to require it.

The sheets are next sent to the lofts to be dried; these are usually situated close to the mill; they are surrounded by moveable lattices for the admission of air, and in some lofts there is a convenience for drying

the paper by hot air when the weather is damp and uncertain. The paper is hung up in *spurs* of five or six sheets, by means of a wooden instrument in the form of a tall T, upon hair ropes called *trebles* or *tribbles*, which are kept stretched as much as possible. The difficulty of drying the paper in this way in our uncertain climate is very great, and in frosty weather the paper is liable to be spoiled by freezing.

Up to this point the paper is unfit for writing on, in consequence of not having been sized; it is, in fact, in the state of white blotting-paper, to which size is never added. The paper-maker's size is produced from the refuse of the tan-yard, consisting of the parings of skins, ears, &c.; the gelatine is extracted by boiling, and after having been carefully strained, a quantity of alum, or smalts, or other pigments calculated to improve the tint or impart a particular hue to the paper, is added. The workman dips a handful of the sheets into a hot solution of the size, and keeps adding to the lot, moving them between his hands that they may freely imbibe the size; having taken them out of the vessel, he inverts them and dips them again; after this the sheets are removed to a press, with a piece of thin board between every handful, and the superfluous size is pressed out and returned to the vessel; the paper is then separated sheet by sheet, returned to the drying-house, and dried very gradually. From this stage it is necessary to handle the paper carefully, as any impressions now communicated to the grain of the paper cannot be effaced.

When thoroughly dry it is conveyed to the *salle*, or finishing-room, where it is again pressed, and sorted into different lots according to its quality; it is then examined by a finisher, who, taking the sheets in his right hand, folds and examines them, and places them one by one on his left arm, until he has a sufficient number for a quire; he then makes the sides parallel, and places them in heaps. If proper care has been taken to assort the lots, an expert

workman can examine and fold as many as six hundred quires in a day. The paper is again pressed, then made up into reams of twenty quires each, and once more put into the press, where it is allowed to remain, if possible, for ten or twelve hours; it is then tied up in a wrapper with a label on it, which is filled up by the manufacturer and the excise officer respectively; the latter weighs the paper and stamps the wrapper, indicating thereby that the amount of duty has been charged to the maker.

In addition to the above finishing processes, two others are sometimes introduced for fine papers—namely, *hot-pressing* and *glazing*. In hot-pressing a number of stout cast-iron plates are heated in an oven, and then put into a screw press in alternate layers with highly glazed pasteboards, between which the paper is placed in open sheets; the hard polished surfaces of the pasteboards, aided by the heat and pressure, impart that beautiful appearance which is so well known to belong to hot-pressed paper. But a yet more smooth and elegant surface is produced by the process of glazing: the sheets of paper are placed separately between very smooth clean copper plates, and these are then passed through rollers which impart a pressure of from twenty to thirty tons; after only three or four such pressures it is called *rolled*, and sometimes also *hot-pressed;* but if passed more frequently through the rollers, the paper acquires a higher surface, and is then called *glazed*.

PAPER-MAKING BY MACHINERY.

The difficult and comparatively slow process of moulding the separate sheets of paper by hand, has to a great extent been superseded by the invention of a most ingenious and beautiful automaton, which has been in use about forty years. "By the agency of a great deal of complicated machinery, so admirably contrived as to produce the intended effect with unerring precision, and in the very best manner, a

process, which in the old system of paper-making occupied about three weeks, is performed in as many minutes! A continuous stream of fluid pulp is, within this brief space of time, and the short distance of thirty feet, not only made into paper, but actually dried, polished, and every separate sheet cut round the edges and rendered completely ready for use. The paper manufactured by this wonderful combination of intelligence and power is at once moderate in price, and, for most purposes, superior in quality, to that which was formerly made by hand.*

Another writer also justly observes, that "this mode being more economical, more rapid, and more powerful, will become henceforth the only one which can be practised without loss. Then will disappear the ancient system of hand-work, which likewise involved the inconveniences, we may say dangers, resulting from combinations among the operatives. The machine-made papers possess many advantages; they can receive, so to speak, unlimited dimensions; they preserve a perfectly uniform thickness throughout all their length; they may be fabricated in every season of the year; nor do they require to be sorted, and trimmed, and hung up in the drying-house; operations which occasioned great waste, amounting to no less than one defective sheet out of every five."†

In attempting to convey a clear idea of this truly wonderful automaton, we must at once admit how faint is the impression produced by any written description in comparison with an attentive examination of the machine itself at work, which the writer of this notice has had an opportunity of bestowing. But he hopes, with the assistance of the frontispiece, to be able to impart to the attentive reader a share of that pleasure of which he so largely participated.

We must first observe that this machine is the invention of Mr. Louis Robert, and was introduced

* M'Culloch, *Commercial Dictionary.*

† Baron Dupin, *as quoted by Dr. Ure.*

into this country about forty years ago by M. Didot of Paris, who, with the assistance of the MM. Fourdrinier, and Mr. Donkin the engineer, succeeded in perfecting the invention, and acquiring a patent right over it; but it is deeply to be lamented that, partly in consequence of the enormous sums of money expended in perfecting the invention, the patentees never obtained any adequate remuneration for this splendid machine, which, as far as they are concerned, is now the property of the country.

We will now proceed to describe a common form of this machine, with a view rather to give an idea of its action, than to detail the large number of minor variations and improvements for which separate patents have been taken out.*

At one extremity of the apartment in which the machine is contained, is a large reservoir constantly supplied with the stuff properly prepared, according to the process already described.† From this reservoir the stuff flows into a spout, through a cock which is opened more or less widely, according to the thickness of the paper to be made. In this spout the stuff is diluted with a quantity of water, and it then flows into a vat, first passing through a sieve, or strainer, in order that it may be freed from the knots and hard substances which may yet remain in it. Previous to the introduction of these strainers, it was the custom to remove knots in the paper by means of sharp knives in the finishing room, but not without injury to the surface of the paper.

There are several forms of strainer, but it will be sufficient to describe one. It consists of a rectangular trough of brass, or gun-metal, about five or six feet long, two feet wide, and four inches deep. The bottom, or strainer, consists of heavy bars, the surfaces of which are highly polished: the spaces between

* See Frontispiece.

† In machine-made paper the size is usually added to the pulp in the beating-engine.

them admit of adjustment, according to the intended quality of the paper; they correspond with the length of the fibres, but are too narrow to allow knots to flow through. One side of the strainer is attached by hinges to the vat, and the other is connected with a set of cam-wheels, by which it is rapidly elevated and depressed with a jerking motion, making about 130 strokes per minute. This jerking motion liberates the fibres, and allows them to pass through. As the knots, &c. accumulate, the workman draws them to one extremity of the strainer by means of a wooden rake, and then shuts off the flow of the stuff by a piece of wood covered with felt, which is passed across the strainer. This leaves the end of the strainer dry, and the workman can then scoop out the knots, &c., and by removing the sluice, leave the strainer unimpeded until the process requires to be repeated.

The stuff having been thus strained is received into the vat, where the fibres are kept from subsiding by a little hog, or agitator. It is allowed to flow from the vat by a number of holes (the size of which can be regulated at pleasure, so as to allow a greater or less quantity to pass) into a little cavity or box, from which it passes over a piece of leather to a cloth of fine wire, on which the web of paper is first formed. This wire-cloth is about twenty-five feet long and five feet wide, and contains about 3,600 holes in the square inch: it is doubled in the form of a jack-towel, and moves upon a number of small copper rollers attached to a frame. A rapid vibratory motion is imparted to the frame, by which the water is made to flow through the wire-cloth, and the fibres of the pulp become felted together. A shallow vessel, called a *save-all*, is placed below the wire-cloth; this receives the water and the minute portions of the pulp, and transmits them through a spout into a revolving box, which returns them again into the vat.

The edges of the paper are formed by deckle straps, composed of alternate layers of linen and

caoutchouc cemented together; they are held in their places by a solid metallic plate, which, however, does not press so firmly as to prevent their motion along the wire-cloth, while they fit sufficiently close to prevent the stuff from flowing off at the sides before the paper is set.

By the draining off of the water, the stuff loses its fluid character, although it still contains a good deal of water. The wire-cloth, with the paper upon it, then passes between two rollers, covered with felt or flannel, which, by a slight pressure, impart a certain amount of firmness to the paper. After this, the paper is removed from the wire by an endless felt; the wire returning back under the two rollers, just noticed, to receive a fresh supply of pulp.

The endless felt conveys the web of paper, which is still very wet, to two iron cylinders, where it receives a very severe pressure; the effect of which is to remove so much of the water that the paper acquires a certain degree of firmness. It is then taken up by a second pair of cylinders, which remove from its surface the mark of the felt impressed by the first pair of rollers.

The web of damp and readily torn pulp next passes from the region of moisture, which now alone prevents it from acquiring strength and firmness, into the region of heat, where it acquires both. A small roller guides it to a large polished cylinder, heated from within by means of steam; from this, it passes to another cylinder still hotter, and once more to a third, which is the hottest of the three. All moisture and roughness of surface have now disappeared; the paper is finally wound upon a reel, and when a certain regulated quantity is collected, it is severed from the machine, and a new reel is placed to collect a further supply.

Such is the wonderful operation of this machine, on which the genius of man is impressed in such distinct characters, that we could not help calling to

mind the expression of a celebrated person, while regarding a grand and beautiful work of art: "If man can produce so wonderful a work as this, how great must be that Being who made man!" And this is the direction which our admiration of human performances should ever take; for we do not lessen the respect due to genius by thinking with reverence of the Author of every good and perfect gift, who has bestowed so surprising an amount of skill and ingenuity on his creatures.

The more closely we examine the beautiful machine above described, the greater will be our admiration of it. The reader will perhaps be surprised to learn, as we were to witness, the fact, that from the moment when the liquid pulp is flowing from the vat, to the final completion of the beautifully polished white paper on the reel, scarcely *two minutes* elapse. To prove this, the gentleman who kindly explained the machine to us, tore off a piece from the edge of the pulp on the wire-cloth, and in about ninety seconds the portion of the paper with the torn edge was travelling round the reel, and was soon buried amid other coils of finished paper. Reminding the reader that this result, in the ordinary state of the weather, could not formerly be obtained in less than seven or eight days, how interesting becomes the calculation as to the amount of work done by this automaton! The machine moves at the rate of from twenty-five to forty feet per minute. If the machine makes a length of web equal to ten yards per minute, it produces six hundred in the hour, or four miles per day of twelve hours. The width of the paper is generally about fifty-four inches. Now, according to Mr. M'Culloch, there are three hundred machines in Great Britain, many of which are at work by night as well as by day; if, therefore, we take twelve hours per day as the average for each, the length of web would be altogether equal to 1200 miles, and the surface would be about three million square yards daily.

The precision with which the machine does its work is not the least admirable of its qualities. The machine travelling at a certain definite rate, the supply of pulp being equally regular, it is obvious that the thickness of the paper must always continue the same, an advantage which does not belong to hand-made paper. Supposing also, that the paper-maker should wish to produce paper of double the ordinary thickness; he can readily do so, either by admitting a double supply of pulp to the machine, while the wire-cloth ravels at the same rate, or by making the wire-cloth travel at only half its ordinary rate, while the supply of pulp remains the same. So, likewise, in order to produce paper thinner than usual, he may accelerate the rate of his machine, or limit the supply of pulp. Thus it is easy to see how tractable, and one is almost tempted to say, intelligent, this truly valuable servant is under proper guidance.

The paper-machine has likewise produced changes and advantages where they were but little expected. Before its introduction the newspapers could not boast of their double sheet, nor could paper be made of sufficient size for such purposes. The largest description of paper used by paper-stainers was called *elephant*, from what was then considered its large size; yet each sheet only measured twenty-eight by twenty-three inches. In order, therefore, to form a length or piece of twelve yards, it was necessary to paste together sixteen or eighteen of these sheets, a plan now rendered unnecessary, because the paper-maker supplies the stainer with sheets of twelve yards each in length. Now that the duty is taken off stained paper, the poorest person can enjoy the comfort of papered walls, instead of the cold cheerless white-wash, which leaves a mark on every thing that touches it.

For communicating engraved impressions to pottery-ware, a paper has been made by the machine, which far surpasses that previously used for the purpose. An eminent potter wrote to the MM. Fourdri-

nier as follows: — "Had not an improvement taken place in the manufacture of paper, the new style of engraving would have been of no use, as the paper previously used was of too coarse a nature to draw from the fair engravings any thing like a clear or perfect impression; and the Staffordshire potteries, as well as the public at large, are, in our opinion, deeply indebted to you for the astonishing improvement that has recently taken place, both as regards china and earthen-ware, more particularly the latter. We have adopted a new mode of printing on china and earthen-ware, which, but for your improved system of making tissue paper, must have utterly failed; our patent machine requiring the paper in such lengths as were impossible to make on the old plan. On referring to our present stock, we find we have one sheet of your paper more than one thousand two hundred yards long." There can, however, scarcely be said to be a limit to the length of paper made by the machine; indeed we have been told of a paper-maker who received an order for so many *miles* of paper in one unbroken length. There is also another effect produced by the machine, for which we cannot but be grateful: it has lowered the price of paper one half, and increased the revenue, "directly and indirectly, by a sum of probably 400,000*l.* per annum."

We cannot take leave of this machine without glancing at one or two of the most remarkable improvements that it has undergone of late years. One of the most eminent improvers in this branch of the useful arts employs a polished hollow brass cylinder, perforated with holes and covered with wire-cloth, which revolves over and just in contact with the prepared pulp: the axis of this cylinder is placed in communication with a pair of air pumps, and by their action the paper is formed; the film of the pulp adheres to the cylinder during its rotation by atmospheric pressure, whereby it becomes drier and of a

far more uniform thickness than upon the horizontal hand-moulds or travelling wire-cloth of Fourdrinier. "When subjected merely to agitation, the water is sucked inward through the cylinder cage, leaving the textile filaments so completely interwoven, as if felted among each other, that they will not separate without breaking, and when dry they will form a sheet of paper of a strength and quality relative to the nature and quality of the pulp. The roll of paper thus formed upon the hollow cylinder is wound off continually upon a second solid one, covered with felt, upon which it is condensed by the pressure of a third revolving cylinder, and is thence delivered to the drying rollers." *

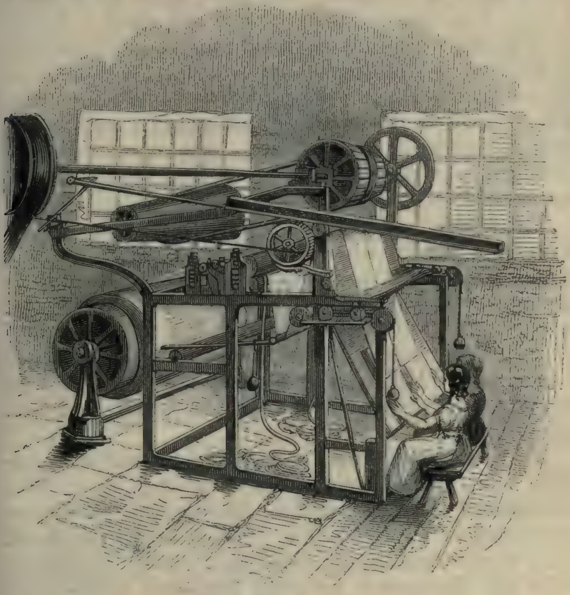
Another important improvement in the paper manufacture is on the principle of veneering in cabinet work. Two webs of paper are made, each by a separate process; and by laying them together while in an early stage, they are rendered inseparable by the pressure to which they are subjected. This paper is used in copper-plate printing; and by adopting a peculiar method of preparing the pulp, and selecting a finer rag for the web which forms the face of the paper, it is much better calculated for taking a fine impression. This admirable invention has put nearly a total stop to the importation of French paper, which was formerly used in considerable quantities by copper-plate printers.

We may also notice the invention of protective paper, which is made by introducing silk threads into the body of the sheet; which paper, by varying the colour of the threads and their distances, admits of great variety of distinguishing characteristics, and Government have made use of it for post-office envelopes and Exchequer bills, as a safeguard against forgery.

Various machines of great ingenuity have been contrived for cutting the paper into sheets of the

* Dibdin. *Bibliographical Decameron.*

required size, after it is removed on reels from the paper machine. One of these, by MM. Fourdrinier, may be briefly noticed. Several reels of paper having been collected, the spindles are placed in grooves in a curved frame, whence the paper is passed round a drum, and then through small rollers. A thin shaving is first cut from the side edges of the paper



PAPER-CUTTING MACHINE.

by means of circular knives; and when the paper has travelled the length necessary to form a sheet, its progress is delayed for an instant by a very ingenious contrivance, and a knife descends and cuts it across. The web then resumes its journey, until it has travelled the length of another sheet, when the knife again descends. The sheets thus severed are arranged into

heaps by children, as in the cut, or they are carried away by a small felt, moved in connexion with the rest of the machinery.

STATISTICS OF THE PAPER-TRADE.

ACCORDING to Mr. M'Culloch there are about 700 paper-mills in England, and from 70 to 80 in Scotland. The number in Ireland is but small. About 27,000 individuals are supposed to be engaged directly in the trade; and besides the workmen employed in the mills, the paper manufacture creates a considerable demand for the labour of mill-wrights, machinists, smiths, carpenters, iron and brass-founders, wire workers, woollen manufacturers, and others, in the machinery and apparatus of the mills.

Till within a few years, all writing, coloured, or wrapping papers were denominated *first class*, and paid a duty of 3*d.* per pound weight, or 28*s.* a cwt.; the *second class* paper referred to that manufactured wholly of tarred ropes, without the tar being previously extracted, and paid a duty of $1\frac{1}{2}$*d.* per lb., or 14*s.* a cwt. Mill boards and scale boards, made of the same materials as second-class paper, paid $2\frac{1}{4}$*d.* per pound, or 21*s.* a cwt. duty.

These distinctions into first and second class papers, and these heavy duties having long been considered injurious, the Commissioners of Excise instituted an inquiry a few years ago, and the result was, a recommendation from them to the legislature, that the distinction between first and second class paper should cease, and that a duty of $1\frac{1}{2}$*d.* per lb. be charged, indiscriminately, on every description of paper. These suggestions were adopted in the year 1836; and, at the same time, the duty of $1\frac{3}{4}$*d.* the square yard charged on paper when printed or stained, over and above the ordinary duty, was then also wholly repealed.

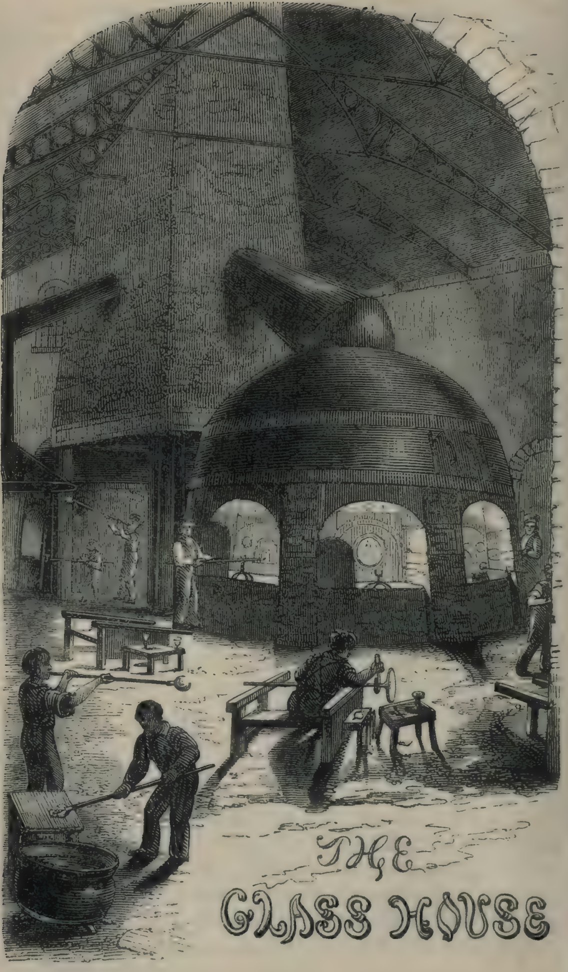
The beneficial effect of this reduction was soon

experienced. In 1835 the net produce of the duties on paper, in the United Kingdom, was 715,743*l.*, of which the duty on stained paper produced 60,141*l.* The latter duty having been totally repealed in 1836, must, therefore, be deducted, in order to ascertain the duty on printing and writing papers, pasteboard, &c., for 1835, to serve as a basis for comparison in subsequent years:—this gives a sum of 655,602*l.* The duty being reduced one half, it follows that, had the consumption continued stationary, the duty would have amounted to 327,801*l.*; whereas it actually amounted, in 1838, to 539,789*l.*, being an increase of sixty-five per cent. In 1841 the amount of duty was 637,255*l.* The reduction of the duty in October, 1836, cannot be expected to have produced, as yet, its full effects; but the degree in which it has already stimulated consumption, may be seen from an account of the quantities used from 1834 to 1841:—

	lbs.		*lbs.*
1834	70,605,889	1838	93,466,286
1835	74,042,650	1839	97,643,823
1836	82,108,947	1840	97,237,358
1837	88,950,845	1841	97,103,548

With respect to the healthfulness of the occupation of the paper manufacturer, there is less to complain of than in many other trades. The paper mills of England are for the most part situated in healthy localities, where the air is pure and exhilarating; and it is also a favourable circumstance, that the manufacture itself demands good ventilation. The most injurious processes are undoubtedly those of rag-cutting and dusting; some of the rag houses are large, lofty, and clean, and in such cases the evil is lessened; but where the inferior sorts of paper are made, or where the rooms are low, the atmosphere is most oppressive. Major Burns, the sub-commissioner appointed by Parliament to report on the state of paper mills in the Kent, Bucks, and Herts district, describing such rooms in his official statement, says, that "all indeed have air, either by opening the win-

dows, or else by setting open the doors at either end, so as to produce a thorough current; still," he says, "in some, where the rags are very dirty or foul, a hurricane blowing through them would fail in clearing the abominably dense atmosphere of heavy dust." The health of aged persons is soon affected by this atmosphere, but young persons do not appear to suffer from it; and the children usually employed do not remain at that department very long. Of the young persons examined by Major Burns, some complained that their work gave them headache or pain in the chest, but, generally speaking, they appeared as healthy as the same class of persons in agricultural employments. "All the young people in paper mills seem a very healthy race indeed, equally so with others of the same class of life working at other employments: they are not so bronzed perhaps as those in agricultural work, but in no other respects inferior in bodily condition. As my inquiries every where excited some alarm among the parents, who seemed afraid that I might be the means of putting a stop to children being employed, their testimony of its comparative healthiness may be questioned as to its impartiality; they one and all said that paper-making was as healthy as any other labour. At the outset of my inquiry, and before any alarm was excited, I took the evidence of a very intelligent journeyman, who says: "I have two sons, one employed in the mills, the other in out-door employments; and I can see no difference in their state of health or constitution." I did not see any one instance of any peculiar disease or deformity; they all seem very well clad, though in Bucks and Herts there was a slight inferiority as to neatness in this respect. The medical men with whom I conversed seemed to think them as healthy as other classes, and, judging from their appearance, and their own statements, they are as well fed."


THE
GLASS HOUSE

THE

MANUFACTURE OF GLASS.

It is unnecessary to comment on the value of a substance which is in constant use among all classes of persons, which admits the light of day to the cottage of the peasant as well as to the palace of royalty, and which is daily and hourly employed both for the requirements of scientific investigation, and for the purposes of ordinary life. Perhaps the well-known remarks of Dr. Johnson best and most concisely express the admirable qualities and uses of glass: "It might contribute to dispose us to a kinder regard for the labours of one another, if we were to consider from what unpromising beginnings the most useful productions of art have probably arisen. Who, when he saw the first sand or ashes, by a casual intenseness of heat, melted into a metalline form, rugged with excrescences and clouded with impurities, would have imagined that in this shapeless lump lay concealed so many conveniences of life, as would, in time, constitute a great part of the happiness of the world? Yet by some such fortuitous liquefaction was mankind taught to procure a body at once, in a high degree, solid and transparent, which might admit the light of the sun, and exclude the violence of the wind; which might extend the sight of the philosopher to new ranges of existence, and charm him at one time with the unbounded extent of the material creation, and at another with the endless subordination of animal life; and what is yet of more importance, might supply the decays of nature, and succour old age

with subsidiary sight. Thus was the first artificer in glass employed, though without his own knowledge or expectation. He was facilitating and prolonging the enjoyment of light, enlarging the avenues of science, and conferring the highest and most lasting pleasures; he was enabling the student to contemplate nature, and the beauty to behold herself."

The word glass is said to have been derived from the Latin for ice *(glacies)*, on account of its resemblance to pure ice; or from the Gaelic name for amber *(glassum)*; or, according to a third conjecture, from an ancient name for woad *(glastum)*, on account of the blue tint which it usually exhibited. The origin of the name, and also the origin of the art of making the substance itself, are, however, involved in great obscurity. Pliny's account of the accidental discovery of the art by the Phœnicians, is a very plausible one, and has been generally received. According to this writer, a merchant vessel, laden with nitre or fossil alkali, was driven ashore on the coast of Palestine, near the mouth of the river Belus, a small stream running from the foot of Mount Carmel in Galilee, into the Mediterranean. The mariners, unable to procure stones to rest their cooking vessels upon, used pieces of their cargo instead. The fire reduced the alkali to a soft state, and incorporating with the river sand, it melted down into a vitreous stream. The circumstance was communicated to the inhabitants of the district, who availed themselves of the hint and engaged in the manufacture of glass.

The high antiquity of the art is undoubted; for not only is glass mentioned by a Greek poet, who flourished four hundred and twenty-three years before the Christian era, but Egyptian mummies of the date of three thousand years ago, are found adorned with beads of earthenware having an external coating of fine glass. Pieces of glass of similar composition have also been found amongst the tombs of Thebes. The

glass-houses of Tyre, an ancient Phœnician city on the coast of Syria, are the first of which there is any account; but those of Sidon and of Alexandria afterwards became equally famous. In these early manufactories, articles of mere ornament seem in the first place to have been solely made. Afterwards the art extended to the making of drinking cups and glasses. The high value set on these, is proved by the fact that the Roman Emperor Nero gave for two drinking cups of glass, with handles, a sum of money equal to 50,000*l.* sterling. At what time window-glass was first manufactured is not precisely known. It could not have been in use at the time of the destruction of Herculaneum, which took place in the reign of the Emperor Titus, for in that city the windows of the largest houses were made with a species of transparent talc. Perhaps the first mention of glass windows is that of St. Jerome, about the year 422. They are also spoken of by a writer of the commencement of the seventh century, and are described as being fastened in with plaster.

The art of glass-making extended from one kingdom to another, and many cities in succession became celebrated for the manufacture. The glass-manufacturers of Rome had become so numerous in the reign of Alexander Severus, (A.D. 220), that a principal quarter was assigned to them in the city, and a tax was laid upon them by the emperor. Venice, receiving the knowledge of the art from Rome, became celebrated in its turn; and the artisans of Murano, near that city, attained great skill in making mirrors, which had been previously made of polished metal. But the most celebrated specimen of ancient glass, was the famous Barberini or Portland Vase, lately contained in the British Museum, the wanton destruction of which has caused so much grief and indignation throughout the kingdom. It was found in the tomb of Alexander Severus, (who died in the year 235,)

and was formed of deep blue glass, ornamented with white opaque figures most skilfully designed and sculptured in the style of cameos.

The art of glass-making was fostered in France by a decree of the government, early in the fourteenth century, to the effect that none, save gentlemen, or the sons of gentlemen, should engage in any branch of the manufacture, even as working artisans: at the same time a royal charter of incorporation, and various important privileges, rendered the cultivation of this art well worthy the attention of families of distinction, whose capital, thus employed in establishing extensive works, was productive of great national benefit, as well as of a large increase of wealth to their own families. Subsequently the altered state of society naturally led to other and less exclusive regulations.

In England, it is averred by some writers, the art was known even in the time of the Druids. This is supposed to be proved by the coloured glass beads and amulets found among Druidical remains in this country. There seems little doubt, however, that these ornaments were procured by the ancient Britons from the Syrian adventurers, who visited these islands, for the purpose of carrying on a traffic with the savage inhabitants. Beads and trinkets are always found attractive to a barbarous race, and are gladly received in exchange for articles of much greater value. Among the most curious trinkets found in barrows or tumuli, are the Druidical glass rings called Glain Nerdyr. These are generally about half as wide as our finger-rings, but much thicker; and it appears that they were employed by the Druids as charms, whereby they might deceive the ignorant. These rings are usually of a green colour, but some are blue, and others variegated with wavy streaks of blue, red, and white. Many of the amulets, &c. above referred to, are of exquisite workmanship, and

could not have been the production of an uncivilized nation.

Although there are no means of determining when glass was first manufactured in England, yet so early as the commencement of the fifteenth century allusions are made to the English manufacture. In a contract, dated 1439, between John Prudde of Westminster, glazier, and the Countess of Warwick, respecting the embellishment of her husband's tomb, the said Prudde is bound to use "no glass of England, but glass from beyond the sea." The manufacture of flint-glass was begun in London, at Savoy House in the Strand, and in Crutched Friars, in the year 1557; and the first plate-glass for mirrors, coach-windows, &c. was made at Lambeth, in 1673, by Venetian artists, brought over by the second duke of Buckingham. A century later, an establishment of great magnitude was undertaken by a body of gentlemen, who obtained a royal charter of incorporation, and were styled "The Governor and Company of British Cast Plate-Glass Manufacturers." They commenced proceedings at Ravenhead, near Prescot, in Lancashire; and unto the present day the company is still flourishing.

Religious edifices in England appear to have been first supplied with glass windows in the year 674, when, according to Bede, some continental workmen were brought over by Abbot Benedict, for the purpose of glazing the church and monastery of Wearmouth. For many centuries afterwards, the use of window-glass was confined to ecclesiastical buildings; so that, even at the close of the twelfth century, the windows of private houses were filled with oil-paper, or wooden lattices. Crown, or window-glass, was manufactured at Crutched Friars in London, in 1557.

The manufacture of glass was introduced into Scotland in the reign of James the Sixth, who granted permission to George Hay to manufacture glass, within the kingdom, for thirty-one years. The

first glass manufactory was erected at Wemyss in Fife; but larger and more complete establishments were afterwards built at Prestonpans and Leith.

It is somewhat remarkable that the Eastern nations, notwithstanding their ingenuity and skill in many respects, have made very little progress in this important manufacture. Glass-working is practised in China, but it is merely the re-manufacture of old or broken glass of foreign make, which is melted and moulded into new forms. Until Europeans settled amongst them, the Hindoos only knew enough of this manufacture to make beads and trinkets. Before that period there was not a house throughout India furnished with glass windows; and so ignorant were the Hindoos of the optical purposes to which glass might be applied, that they were "astonished and confounded at the effects of a common spy-glass."

MATERIALS OF THE MANUFACTURE.

Glass, in the ordinary acceptation of the word, is a substance composed of silex and an alkali. Under the influence of a great heat, these two substances unite together and form a fluid transparent compound, capable of being drawn out into the finest threads, moulded into articles of use and beauty, or spread out into sheets for glazing our windows, or adorning our apartments. The use of the alkali seems to be to make the silex soluble; it is, however, uncertain whether glass is really a solution of silex in an alkali, or of an alkali in silex.

Five distinct qualities of glass are manufactured for domestic purposes; viz.—

1.—Flint, or crystal glass.
2.—Plate-glass, or glass of pure soda.
3.—Crown-glass, or best window-glass.
4.—Broad-glass, a coarse window-glass.
5.—Bottle, or coarse green glass.

The two ingredients necessary to the formation of

all these varieties of glass, are silex and an alkali; the different qualities of glass depending upon the purity of the materials employed, as also upon the addition of other materials, such as nitre, oxide of lead, black oxide of manganese, white oxide of arsenic, borax, and lime.

Silex is abundantly distributed throughout the mineral world: flint is almost entirely composed of it, and this substance being used in the manufacture, gave to flint-glass its distinctive name. But the most convenient source of silex for the glass-maker, is sea sand, which requires scarcely any other preparation than careful washing. For the finer descriptions of ware it is necessary to use the fine white sand usually obtained from Lynn in Norfolk, or from Alum Bay in the Isle of Wight.

The alkalies employed in making glass are the carbonates of soda or of potash. During the progress of the manufacture the carbonic acid of these salts is dissipated, while the alkali and the silex unite together. For flint-glass, pearlash, which is a purer form of potash, is selected, and this is subjected to a further purifying process before it is fit for use. For the coarser kinds of glass, barilla, kelp, or wood ashes, are used, which contain many impurities; among which may be mentioned a variable quantity of iron, the effect of which is to impart a greenish tinge to glass. To the other materials is added a small portion of nitre, the oxygen of which allows the combustion and consequent dissipation of any carbonaceous matter which may be present among the other ingredients.

Oxide of lead, in the form either of litharge or minium, is used largely in making flint glass. Its uses are many; it acts as a powerful flux to the other materials, enabling them to vitrify at comparatively low temperatures; it also increases the density of the glass, and imparts to it greater tenacity when red hot, for which reason it can be more easily worked; and it also enables the glass to resist sudden

changes of temperature. It has, however, its defects, especially when used in large proportions; the glass then is so soft that it is easily scratched and injured; it becomes corroded by many acrid fluids, and the glass is not of uniform density, that at the bottom of the pot containing a larger proportion of litharge, and being consequently heavier than the upper portions: the effect of this is to give a wavy appearance to the glass, which is highly objectionable, especially in optical instruments.

Black oxide of manganese (or *glass soap*, as it is sometimes called) is used to get rid of any colour which the impurity of the materials may have imparted to the glass, especially the green tinge, which indicates the presence of iron. The action of this substance is exceedingly curious. When added to glass it imparts a purple colour, which becomes nearly black, according to the quantity employed. If while the coloured mass is in a state of fusion, white arsenic, charcoal, or other carbonaceous matter be added, an effervescence takes place, the colour gradually disappears, and the glass becomes colourless and transparent. The manganese also assists the fusion of the earthy materials, and increases the density of the glass; but it is liable to the same objection as the oxide of lead, that of settling to the bottom of the pot, and giving unequal density to the glass.

Arsenic is used not only to correct the colour of the manganese, but as a flux: it is also of use to dissipate any carbonaceous matter which may exist among the materials.

The use of borax is chiefly confined to plate-glass; it enables the liquid mass to flow with freedom, whereby specks and bubbles, which would impair the beauty of the plate, are avoided.

Lime is a cheap and useful flux, requiring however to be used sparingly, as it otherwise imparts a cloudy appearance to the glass, and corrodes the pots in which the materials are fused.

PREPARATION OF THE MATERIALS.—THE FURNACES AND GLASS-POTS.

THE proportions in which the materials are mixed, differ according to the kind of glass to be made; they also differ in different glass-houses for the same kind of glass. The ingredients are mixed in large wooden troughs or boxes, and then undergo a calcination previous to their more perfect fusion in the glass-house. This process is called *fritting*, and the calcined materials *frit*. The chief object of the process is to effect a chemical union between the ingredients at a moderate heat; otherwise the intense heat of the furnace would dissipate the alkali in vapour before it had time to unite with the silex. Other uses of fritting are to drive off all moisture and carbonic acid from the materials, to prevent them from swelling up in the pots, and to destroy all carbonaceous matters that may be present.

The fritting furnace, called *calcar*, is an oven about ten feet long, seven feet wide, and two feet high. The flame is made to reverberate from the crown of the furnace back to the frit. The temperature is gradually raised until the materials have fused into a pasty mass, in which state they are maintained three or four days. The frit is then removed, and before it has time to solidify it is cut into square cakes, and stored up for future use. In this state it is a brittle, crumbling substance, not unlike alum in appearance. According to some manufacturers frit improves in quality by being kept a long time.

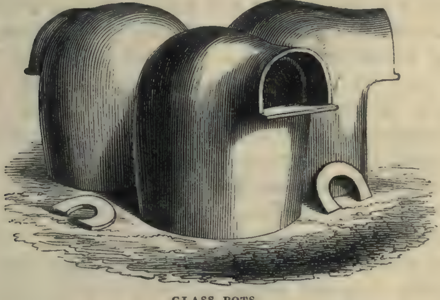
The construction of a glass furnace is of considerable importance; for it has to maintain the glass pots at an intense heat capable of melting the frit, but at the same time it should not be liable to destruction. Clay is the chief material used in the walls of the furnace and in the pots. The clay is mixed with a portion of sand, sufficient to make it work easily, to dry into a compact mass, and to resist the action of

the fire for a length of time. Too much sand renders the clay liable to vitrify and separate from the walls. The external form of the furnace is usually that of a huge cone rising from a circular base, and terminating in the chimney. The form of the interior is that of a dome supported upon arches. Below these are flues for the admission of air, which rising through the bars which occupy the centre of the floor of the furnace, the flame and heated air surround the pots, and thence enter the chimney from the centre of the dome.

The crucibles, or glass pots in which the frit is melted, are made to vary in size according to the objects of the manufacturer; each pot is sometimes large enough to contain a ton of glass; although from fourteen to sixteen hundredweight is the more usual capacity. Twelve of these pots are usually placed in the circumference of each furnace, the mouth of each pot passing into an opening made in the wall of the kiln; so that the pots can be readily charged and their contents withdrawn by the workmen, who stand in recesses formed by projections of the masonry.

The arrangements of the furnace in Messrs. Pellatt's glass-house (represented in the frontispiece) differ somewhat from the above description. Instead of one large twelve-pot furnace, two smaller ones are in use; these contain the same number of pots as the large furnace formerly employed; but the internal area of the two being together equal to only one-half that of the old furnace, the pots are necessarily brought more within the influence of the fire. The same chimney is made to serve for both furnaces. It is supported at the four corners upon massive pillars, so that each furnace has an open space all round it. It is not, however, necessary to work both furnaces at once; nor is this done except when trade is unusually brisk. It is said, that by means of this alteration the weekly expenditure of coals has been lessened to the extent of ten chaldrons.

The crucibles, or glass-pots, are made at the glass-house, and are the subjects of great anxiety and care on the part of the manufacturer, as on their stability much of the success of his operations depends. They are usually made with five parts of Stourbridge fine clay, and one part of old broken crucibles ground to powder. They are manufactured in the winter season only, in order that they may not dry too rapidly. The clay is kneaded by the workman with his naked feet; he turns it over and over, and subjects every part to pressure—the object being to produce a consistent, equable mass, entirely free from air bubbles; for these, by their expansion in the furnace, would cause the fracture of the pot. The attempts to substitute machinery for the naked feet of the workmen in kneading the clay, have entirely failed.



GLASS POTS.

A moderately sized melting-pot holds about fourteen hundredweight of glass: its appearance may be judged of by the accompanying figures better than by description. It is cylindrical in shape, with a domed top and a flat base; and has an opening near the top of the cylinder. The highest is about two feet, the diameter two and three quarter feet, and the clay from two to three inches thick. These pots are built up with rolls of the well-kneaded clay, care being taken to exclude every particle of air from

between the rolls, and to form every part of the vessel of uniform thickness. The potter usually completes four pots in a week, working a little at each pot every day.

The pots are allowed to remain during several months in the room where they are made, in order to part with their moisture, and to solidify in an equable manner. During this time the temperature of the room is gradually raised. When a new pot is required in the furnace, it is first annealed, in order to prepare it for the intense heat to which it is about to be exposed. The annealing furnace is a sort of room, or oven, on a level with the floor of the glass-house, and capable of holding several pots. Flame from an adjacent furnace is made to reverberate into it, and thus the pots are gradually brought to a red and then to a white heat, and are maintained at this during a few days. The pot is lifted out of the oven while in this heated state, and set in the furnace without being allowed to cool, or causing any diminution of the heat of the furnace. The reader will, therefore, readily suppose that the "setting a new pot" is one of the most tremendous operations of the glass-house.

Through the kindness of Mr. Pellatt the writer was present during one of these operations. The first part of the process was to get out the old pot, which had done duty for seven months, but was now rendered worthless from having "sprung a leak." The heat of the glass furnace is sufficiently intense to an unpractised looker-on during the ordinary operations of glass-blowing, &c., when the fire is covered up by badly conducting materials, with the exception of a few apertures for getting out the glass, and heating the tools, &c.; but now the wall of one of the arches was to be taken down, thus exposing the men to the naked heat of a huge furnace. The men were about twenty-four in number, two or three of whom worked at a time, and were frequently relieved.

The difficulty of getting out the old pot was very great, owing to the firm hold which it had on the floor of the furnace: it was, in fact, cemented to the floor by the glass which escaped from the crack whereby it was rendered useless; and this cementing glass became more and more difficult to loosen, as the current of air, which rushed towards the now large opening, solidified the glass. The men, therefore, had to work at the bottom of the crucible with huge crow-bars, resting upon a little roller, supported upon an iron frame, placed at the mouth of the opening. The blows of the crow-bars brought away large pieces of glass, soiled and blackened by the ashes of the furnace, fire bricks, masses of clay, and sometimes pieces of the pot itself. The crow-bar was held by two or three men, who gave a few blows, and then retreated from the fierce heat, to be succeeded by two or three others, who, in like manner, performed their minute's work, and retreated to the shelter furnished by the massive wall of the furnace.

At length the pot being loosened all round, its base was elevated by crow-bars, and a low iron truck moving on two wheels thrust under it; and thus it was withdrawn and thrown aside at some distance. The floods of heat which now radiated from the opening were terrible; the side of the pot nearest the opening, by its contact with the air, had cooled somewhat, and served, to some extent, to keep off the full glare of the furnace; but now there was no shield—no defence. And here was, perhaps, the most arduous part of the operation; the floor of the furnace had to be prepared to receive the new pot: for this purpose the most fire-proof workman was selected; he was furnished with a kind of shovel, with a handle fourteen or fifteen feet long, resting on the roller before noticed. A number of men stood by, each holding a large kneaded piece of fire-clay—one of them, as he was directed, went up to the mouth of the opening, and placing his piece of clay on the shovel, quickly

retreated. The clay was then deposited on the bed of the furnace, and worked quickly with the spade; and thus piece after piece was deposited until a tolerably even bed was produced. Another party of men then went with the iron truck to the annealing oven; its folding doors being thrown open, revealed the pots, now mounted at about a yard from the floor, glowing at a bright red heat. To thrust in the truck under one of them and bring it out, was the work of a moment; it was quickly wheeled to the furnace; deposited in its place, and being held by crow-bars, the truck was drawn out from under it: the whole being accomplished with a dexterous celerity which pleased and satisfied the looker on.

The next part of the operation was to close up the opening, for which purpose two heated masks of fire-clay were brought on shovels; these rose from the ground about a yard high; upon them were placed bricks and fire-clay. The mouth of the pot being closed with a temporary screen of clay, the rest of the opening was closed up with great despatch by a number of men, each bearing a portion of clay or a brick, which he knew precisely where to deposit.

The new pot having safely úndergone all these severe tests, has to be proved by a yet more arduous one. Will it hold glass? is the anxious inquiry of the manufacturer. When the proper temperature has been regained, it is loaded with frit, and watched every hour until the workmen are again ready to help themselves from its contents. The surface is watched to see that it does not fall; for if it does, there is a crack, and the glass is leaking away. Should this be the case, the wall of the arch is again hastily pulled down; cold air is admitted; the glass about the crack solidifies, and thus the contents of the pot (often from sixteen to twenty hundredweight of glass) are saved.

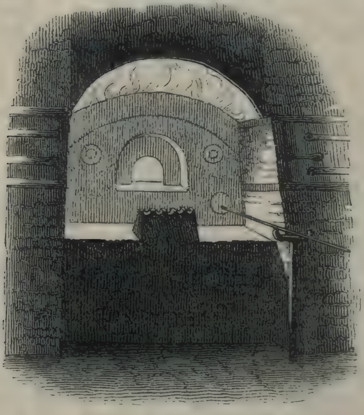
The arrangements with respect to the working hours in a glass-house are somewhat peculiar. The

intense heat required to melt the glass renders it necessary always to maintain the furnace in a vivid state of combustion; for if once suffered to go out or to cool down, there would be great loss of time and fuel in getting up the heat again. When the pots are filled with fresh materials for flint-glass, about forty-eight hours are required to bring them into a proper working form; the supply of *metal* (as the molten glass is called) is therefore proportionate to the demands of the manufactory during the first four working days of the week: the men working incessantly night and day in sets, which relieve each other every six hours. By Friday morning the pots are so far emptied as to require re-filling, which being done, the fire is urged briskly; the pots are repeatedly watched and skimmed, and portions taken out from time to time to test the quality of the metal, so that by Monday morning every thing is ready for the usual operations of the glass-house. It is to be regretted that the long-continued application of heat to the glass-pots, renders it necessary to employ some of the men on Sunday; but as the whole of their duty on that day is simply to watch the furnace, it is so arranged that the attendance of each workman one Sunday in every four is all that is required.

In the manufacture of flint-glass, the materials, being in a state of considerable purity, are not always fritted; but being intimately mixed, are cast, by means of clean iron shovels, into the pots when at a clear white heat. When the materials have melted down, the operation is repeated until the pot is full of the molten metal. The mouth of the crucible is stopped up with clay, in order to confine the heat, a narrow opening being left, through which the contents may be examined, and impurities removed.

The materials do not at once melt into a clear limpid glass: they acquire their transparency by slow degrees, as a white porous scum rises to the surface of the mass, and is skimmed off. This scum is called *sandiver*, or *glass gall*, and consists chiefly

of impurities existing in the alkali, which having no affinity for silex, and being lighter than the melted glass, rise to the surface, and, unless removed, would soon disperse in vapour, and corrode the top of the crucible. Another portion of sandiver, consisting of vitrified metallic and earthy impurities, is sometimes found at the bottom of the pots, and is removed before the pots are refilled. Sandiver is sold to the refiners of metals, who find it useful as a powerful flux. If the sandiver were allowed to remain in the glass, articles formed of it would be cloudy and full of bubbles. By a long continuance of the heat this substance is got rid of, and other impurities are also removed. The glass increases in flexibility and weight, and becomes colourless and translucent. To those who have the courage to look into the furnace, the pot of glass is a very beautiful sight; but the very attempt to view it is painful, from the intense



MOUTH OF THE FURNACE.

heat. But if the spectator is furnished with a square of glass set in a wooden frame, he will find this to be a very effectual screen from the heat, enabling him to witness all the operations of the glass-house (even the setting of a new pot) with little comparative

inconvenience. The writer found, that by wearing spectacles he could look into the furnace, which, with the unguarded eye, it was impossible to do.

When the materials are thoroughly vitrified, the mass is in too fluid a state to be worked. The temperature of the glass-pot is, therefore, somewhat lowered by stopping the draught of the furnace in that part where the crucible is placed; the clay with which its mouth was partially closed is removed, and the glass-blower can now commence his operations. During the time employed in working a pot of glass, which varies from five to twenty hours, or longer, its consistence should be maintained at about the same point: this, therefore, calls for much attention on the part of the workmen. As the glass may be kept in a melted state without injury, it is usual to work up the contents of two or three of the pots before the others are touched.

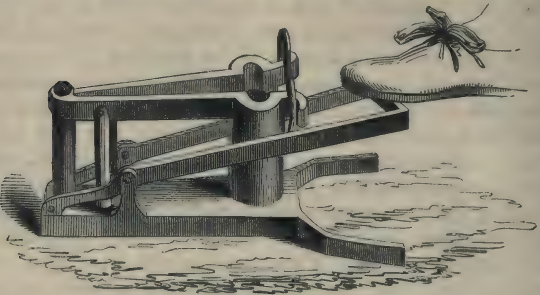
MANUFACTURE OF ARTICLES IN FLINT-GLASS.

The various articles of use or beauty which are made of flint-glass, are, for the most part, produced by blowing the melted glass into form, and moulding it by hand, with the assistance of a few simple tools.

The chief implement of the glass-blower is a hollow iron tube, or rod, four or five feet long, and about one-eighth of an inch bore, and technically called *the iron*. By dipping one end of this tube into the pot, and turning it about several times, the workman collects upon it a quantity of melted glass sufficient to form the intended article.

On one occasion, when the writer visited the glass-house, a set of men were engaged in making eight-ounce phials. Having collected upon the iron a quantity sufficient for making one phial, (which is judged of very accurately by the eye,) the man held the rod vertically for a moment, and gave it a slight jerk, the effect of which was to lengthen out the glass beyond the rod: he then rolled the red-hot lump upon a smooth table of iron, in order to give it consistency

and form; pinched the upper part of it with pliers, in order to form the neck; then placing the glass in a



FLINT-GLASS BOTTLE MOULD.

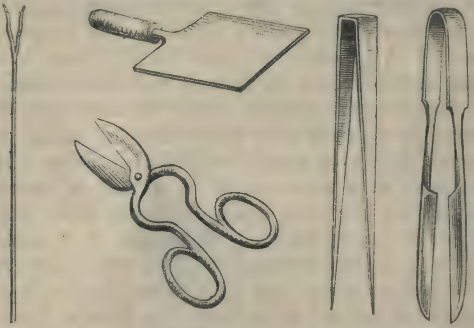
brass mould, (the two halves of which were brought together by pressing on a pedal,) he blew down the tube, the effect of which was to hollow out the glass and make it fill up the mould, the form of which it of

MAKING BOTTLES.

course immediately assumed. On removing his foot from the pedal, the mould fell asunder, and a phial was seen adhering to the tube; it was detached by contact with a piece of cold iron; then taken up on the end of a heated rod by another workman, who softening the bottle at the mouth of the furnace, touched it up and finished it off with great rapidity; it was then conveyed by a boy to the annealing oven. The same mould was used by two blowers, one of whom was collecting and rolling his glass, while the other was blowing it out. Probably not more than a minute was consumed about each bottle.

In another part of the glass-house, a superior set of men were engaged in making oval preparation-glasses. A quantity of glass having been collected at the end of the iron, it was rolled out, and then blown into a pear-shaped form; the man then swung it round in a gentle whirl, the effect of which was to elongate it into a nearly cylindrical form. It was then given to a man seated in a sort of arm-chair, who, placing the tube upon the chair arms, rolled it backwards and forwards. By means of a scale and compasses, he ascertained whether the cylinder was of the proper size; the first man then collected a quantity of melted glass upon an iron rod, called a *punt* or *pontil*,—which is a solid iron rod, smaller and lighter than the tube used for blowing,—and handed it to the man in the chair, who, pinching a portion of it, detached a large lump, and allowed it to fall upon the lower end of the cylinder, to which it instantly adhered, and formed the bottom of the vessel. He then took a flat piece of wood from a bucket of water, and pressed it against the lump of red-hot glass, rolling the tube all the time: the effect of which was to spread out the glass into a flat surface or base. By this time the glass had cooled below the working heat; the man therefore held it in the mouth of the glass-pot, turning it round all the time, until it was again softened: on withdrawing it, he resumed his

seat in the arm-chair, and pressing the two opposite sides of the cylinder against the *marver*, (as the flat iron table is called,) the cylinder was converted into an oval: he again placed the tube on the arm-chair, when a boy stooped down, and blew through it, the effect of which was to distend the glass to the proper dimensions. Great care is required in regulating these operations, in order that the vessel may be of the proper dimensions: the compasses and scale are frequently applied, as also an iron instrument, formed something like a pair of sugar-tongs, with which the vessel is moulded to the required dimensions.



GLASS-BLOWER'S TOOLS.

The oval being properly formed, and its base or foot being worked to the requisite shape, the vessel was now transferred to the punt; for which purpose a boy having collected a small quantity of melted glass at one end, applied it to the centre of the base of the vessel, where it adhered firmly: the end attached to the iron tube was easily separated from it, by touching it with a small piece of wet or cold iron. Another workman now took the vessel mounted on the punt, and proceeded to fashion the mouth and upper parts of the article: he first softened it at the furnace, then opened the mouth, and cut away any superabundant material with scissors, with as much ease as he could

divide a piece of soft leather. If the vessel was not long enough, he swung it to and fro, and dexterously whirled it in a circle through the air, whereby the soft red-hot glass easily yielded to the centrifugal force,

GLASS-BLOWER AT WORK.

and was elongated. He then sat in the chair, and rolling the tube to and fro, finished it according to the required pattern, turning over a portion of the glass to form the upper rim; bending it to form a lip, and constantly testing the progress of his work by his scale and compasses.

It is not easy to impart to the reader the admiration excited in the spectator at the sight of these simple and beautiful operations, on a material which we are accustomed to consider so fragile and unyielding. It is indeed interesting to witness the ease and skill with which the workman rolls and pulls, whirls, divides, and joins the plastic material, whereby he rapidly converts a glowing lump of shapeless matter into a useful and elegant article.

The moment the article is finished, it is detached from the punt into a wooden shovel, and immediately conveyed by a boy to the annealing oven. It is still

very hot, and requires to be cooled gradually. Without this, it would be liable to crack at every change of temperature, and a scratch, or even a touch, would often be sufficient to destroy it.

The annealing oven, or lier, is a long, low-arched chamber, heated at the end which opens into the glass-house, and furnished with shallow iron trays, called *lier-pans*, or *fraiches*, which can be pushed along the level bottom of the chamber. Newly made articles are first placed on these trays, in the hottest part of the oven; as the trays are filled, they are pushed forward towards the cooler end, where they are taken out after the lapse of many hours, at a temperature not much above that of the atmosphere. The articles being thus gradually allowed to part with their heat, they contract into a uniform and consistent substance. The time allowed for annealing varies with the bulk of the articles: those which are thin require only a few hours' exposure: large and thick articles require a longer time, and a greater heat when first placed in the oven.

THE ANNEALING OVEN.

MANUFACTURE OF CROWN-GLASS.

Crown-glass, or that used for windows, is required to be much harder than flint-glass, in order to resist the action of the weather. On this account, no lead or metallic oxide is used in its preparation; and as it cannot therefore be so readily fashioned in a variety of shapes, the principal demand is for those enormous discs, the halves of which may be seen in the glazier's crates.

The materials of crown-glass, as of the other descriptions of glass, differ slightly in their nature and proportions in different manufactories. Sand and soda are the essential ingredients, to which are sometimes added minute portions of borax, arsenic, and manganese; and a large proportion of *cullet*, or broken crown-glass, is subsequently added. The materials are first fritted in a large reverberating furnace, the mixture being well worked together with iron paddles, shovels, and rakes, with long handles. In about four hours the fritting is complete. The founding-pots are then filled up with blocks of frit, and the furnace is powerfully urged by opening all the subterranean passages to its grate. In about eight or ten hours a fresh charge of frit can be added. In sixteen hours vitrification has taken place, and a large quantity of sandiver is floating over the surface. This being skimmed off, the pot is ready to receive its *topping* of cullet, which is shovelled in at short intervals. The heat is still continued during some hours; more sandiver is skimmed off; and as the fusion proceeds, a quantity of gas, called the *boil,* is given off. At the end of about forty hours from first charging the pots, the glass is again carefully skimmed, and the working of the pots commences.

It should be remarked that the arrangement of a crown-glass furnace differs in some particulars from

that used for flint-glass; but we need not pause to detail these. The glass-pots, too, are cylindrical in shape, without any hood or cover.

The workmen having collected a quantity of molten glass at the end of his rod, by dipping it repeatedly into the crucible, sufficient to form a sheet of glass, which generally weighs from ten to eleven pounds, rolls it on the iron plate before noticed, and then blows it out into a pear-shape, taking care that the air within the cavity is surrounded with an equal body of glass, and correcting any inequality by rolling it on the marver. He now heats the bulb in the fire, so as to form the glass at the end of the tube, and by a dexterous swing lengthens out the bulb. To extend the neck of the pear, he rolls it over a smooth iron rod, and then flattens the end opposite to the tube by pressure against a plane surface. A small portion of melted glass is then collected at the end of a punt, and is applied to the centre of this flattened part: the hollow tube is then removed by wetting the glass, leaving a circular hole about two inches in diameter. The glass is next carried to an opening in the furnace, called the *bottoming hole*, where it is exposed to the action of flame. A slight wall erected before one half of this hole screens the workman from the heat, but leaves room for working the glass. The man begins to twirl the punt slowly at first, then more and more rapidly; the glass yields to the centrifugal force; its diameter becomes greater and greater; the hole left by the removal of the tube expands proportionately, until at length the doubled portion flies open, and the glass is converted into a plane disc, four or five feet in diameter; of uniform thickness throughout, except at the point where it is attached to the iron rod, where there is a lump called the *bull's eye*. The plate is then removed to the annealing oven, and placed on its edge.

Crown-glass is sold in *crates*, or *sides*, consisting each of twelve of the discs just described. It is sold,

according to its quality, as *firsts*, *seconds*, *thirds*, and *fourths:* the fourth quality producing a price about one-half that of the first. These variations depend for the most part upon the temperature of the furnace, which being once suffered to fall, it becomes very difficult to raise it again, on account of glass being so very imperfect a conductor of heat. In a large glass-house the greater proportion of glass usually consists of seconds and thirds; about one-third of the quantity is of the first quality, and it very seldom descends to fourths.

Broad-glass is a coarser description of window-glass, made of inferior materials, and by a process somewhat different from that just described, but sufficiently similar to render a description unnecessary.

The fact may, perhaps, excite surprise, that the principal part of the manufacture of glass in Great Britain consists of common green bottle-glass. In the year 1840, duty was levied upon no less than 26,286 tons of bottle-glass, while the total quantity of all the other descriptions of glass, during the same year, was only 14,720 tons. To account for this enormous demand, it may be stated that not only are bottles made of this kind of glass, but a variety of articles useful in the chemical and other arts: such as retorts, subliming vessels, tubes, and carboys; this kind of glass resisting the action of heat and of corrosive liquids much better than flint-glass; a quality which is due, in great measure, to the coarseness of the materials employed in the manufacture, which requiring an intense heat for their fusion, and the fluxing materials being of an earthy nature, the resulting glass is exceedingly hard and durable.

The manufacturers of this kind of glass have hitherto been restricted to the use of the commonest sea or river sand, lest the revenue should suffer by bottle-glass becoming the successful rival of flint-glass, which paid about eight times the amount of duty; but now that the duties on every kind of glass are

repealed, the manufacturer is at liberty to introduce any and what improvements he may please; and, doubtless, a marked improvement will be noticed in this branch of the manufacture. It is, therefore, partly for this reason that we do not describe processes which may soon cease to be practised, and also because the usual method of making bottles does not greatly differ from that already described for phials of flint-glass.

MANUFACTURE OF PLATE-GLASS.

In the manufacture of plate-glass it is of the utmost importance to select such materials as will fuse into a freely flowing liquid, because in casting large plates, this quality of flowing freely is necessary to ensure the absence of streaks or bubbles. In this respect soda is found to be preferable to potash; the sand must be of the finest and whitest kind. Lime is also added, for assisting the fusibility of the silex and alkali. Manganese and oxide of cobalt are used as decolouring substances, the action of which is very remarkable: the effect of the manganese is to impart a red tinge, but when mixed in proper proportion with the blue of the cobalt, and the natural yellow tinge of the other materials, the three colours (which are the primary colours constituting white light) combine, leaving the glass colourless.

In preparing the fresh materials, a considerable quantity of pounded fragments of glass is used. There is always a supply of this material produced from what is spilt in casting, and from the ends and edges cut off in shaping the plates.

The proportion in which these materials are mixed varies at different plate-glass works; but, according to Mr. Parkes, the following proportions produce

plates of the best quality. The quantities indicated will produce one pot of metal, equal to 1,200 pounds of good plate-glass.

Lynn sand, previously well washed and dried,	720 parts.
Alkaline salt, containing 40 per cent. of soda,	450
Lime, slaked and sifted	80
Nitre	25
Cullet	425
	1700

The sand, lime, soda, and manganese, being mixed with the greatest care, are fritted in small furnaces during six hours, the materials being carefully stirred so long as vapour is given off, and until the materials sink down into a quiet homogeneous mass. The cobalt and broken glass are then added.

The frit requires an exposure of nearly forty hours to a strong heat, before the glass is ready to be cast. When the glass is properly refined, it is gradually removed, by means of a copper ladle, from the glass-pot into a smaller crucible, called a *cuvette*, which stands empty in the furnace exposed to the full degree of its heat. The size of the crucible is made to vary according to the dimensions of the plates intended to be cast. The proper quantity of glass being collected, the cuvette is allowed to remain some hours in the furnace, to get rid of air bubbles. Samples are taken out from time to time, in order to judge of the fitness of the glass for casting.

The glass is poured out or cast upon tables with perfectly smooth and level metallic surfaces. The British Plate-Glass Company make use of an iron table, or plate of cast-iron, fifteen feet long, nine wide, and six inches thick. Its weight is nearly fourteen tons; it is supported on castors, and moved about to the mouths of the different annealing ovens, as occasion requires.

The glass-foundry at Ravenhead was till lately the largest room, under one roof, that has ever yet been

erected in this kingdom; its dimensions being 339 feet by 155 feet, and height in proportion.* The melting furnaces are ranged down the centre; the annealing ovens are on each side of the foundry, each oven being 16 feet wide, and 40 feet deep; their floors are on a level with the surface of the casting table, so that the plates of glass are quickly and easily removed from it into the ovens.

The melted glass in the cuvette being in a fit state for casting, this crucible is lifted out of the furnace by means of a crane, and being placed on a low carriage it is conveyed to the casting table, which stands as near as possible to the annealing oven destined to receive the plate. The utmost care is taken to prevent any dust or dirt, or scum, from mingling with the glass; the outside of the cuvette is cleaned, and the surface of the glass is skimmed. The cuvette is then clasped by pliers, and being wound up to a sufficient height, it is turned over and moved quickly across the table, depositing the glass in an equable manner. "The spectacle of such a vast body of melted glass formed at once from an immense crucible, on a metallic table of great magnitude, is truly grand; and the variety of colours which the plate exhibits immediately after the roller has passed over it, renders this an operation far more splendid and interesting than can possibly be described."

The thickness of the plate is regulated by ribs of metal placed along the whole length of each side. A rib is also held at the lower end of the table. A large copper roller, made perfectly true and smooth, extending across the table, and resting on the side ribs, is then set in motion, and the glass, during its progress, is rolled out into a sheet of uniform breadth and thickness.

During the whole of this process it is necessary to keep the apartment as free from disturbance as

* Marshall's flax-mill at Leeds, erected about four years ago, is about 400 feet by 216 feet.

possible, lest the surface of the glass be disturbed, and the plate impaired in value. As soon as the glass is set, it is carefully inspected, and should any flaws or bubbles appear, the plate is divided by cutting through them. It is then slipped from the table into the annealing oven, where it is allowed to remain during about fifteen days in a horizontal position, the heat of the oven being gradually reduced until the plate is cold.

The plate is then taken out and squared, by cutting off the edges with a diamond, guided by a square rule. It is next removed to the grinding apartment, where it is imbedded in plaster of Paris upon a table; and a similar plate being imbedded in a frame, the two glass surfaces are rubbed together, a mixture of flint-powder and water being interposed. When one side is sufficiently ground it is turned over, so as to present the other surface, to be ground in the same manner. In this process a certain amount of pressure is required, and as the grinding proceeds, the upper plate is loaded with weights.

The effect of this grinding is to remove all inequalities from the surfaces, but they are, as yet, too rough to be polished; they are therefore again ground with emery powder of increasing degrees of fineness, the effect of which is to make them perfectly smooth and even, although opaque or deadened. The plates are again rigidly examined, and should any flaws or defects appear, they are cut up into smaller plates, so as to leave the blemishes at their edges. It is important to divide the plate into as few pieces as possible, since the value of many small plates is not to be compared with that of one plate equal to them all in area.

The plates are polished with the brown red oxide of iron,—known in the arts as *crocus*, or *colcothar*,—moistened with water; this is applied by means of a hard elastic woollen cushion, furnished with a handle, and rubbed backwards and forwards over the surface

of the plate. This is sometimes done by machinery. Much skill is required to produce a high and, at the same time, a uniform degree of polish on the plate. When both sides are polished, the plate is washed and placed, each side in its turn, upon a dark blue or black cloth, which, by moderating the quantity of light, enables the eye to judge whether the whole surface has been equally polished. If not, the defective parts are retouched by a small polishing cushion.

STATISTICS.

The glass manufacture has long been a considerable branch of industry, and a source of revenue in this kingdom; and although it has had to contend against the unfettered manufacturers of the continent, yet it has successfully rivalled them, except in some of the ornamental departments. The most costly branch of the art, the manufacture of plate-glass, has made such progress, that English plate-glass is now even preferred to the French; while our flint-glass is superior to any in the world.

Still, however, the demand for glass has not kept pace with the growth of our population, and with our increased means of commanding the conveniences of life. Mr. Porter attributes this deficiency to the high duties which have been imposed on the manufacture, while "the processes of the manufacture have been so interfered with by the regulations necessary to collect those duties, as to prevent the introduction of many improvements;" and, "in order to work profitably under those regulations, it has been necessary to carry on the manufacture upon so large a scale, as to create a virtual monopoly, of some of its branches at least, in the hands of a few — a state of things generally unfriendly to improvement."

Now that the duty is entirely removed from glass, the improvement of the manufacture will, doubtless,

proceed at a rate which cannot be calculated; new processes will be invented, and glass will be applied to uses of which we have, as yet, but little conception. Nearly all the materials of which glass is composed, are abundantly produced in this country, and the rest can be procured at as cheap a rate as in any other manufacturing country. The art of the glass-maker is very simple; his implements are few and inexpensive, and it can be prosecuted on a small as well as a large scale. All these encouraging circumstances are most favourable to the rapid improvement of the manufacture. An increased knowledge of the art of design among the operatives, and an extended application of chemistry to the production of colours in glass, would soon enable us to compete successfully with the manufacturers of Bohemia and France.

The choice of the principal seats of any manufacture depends, in great measure, upon the facility with which the raw materials, or the fuel, can be procured. Thus Newcastle and South Shields are the principal seats of the manufacture of crown and bottle-glass, in consequence of the excessive cheapness of small coal, or slack, in that district. The largest manufacture of crown-glass is near Birmingham. Considerable manufactures of flint and of other glass are carried on at Dudley, Stourbridge, Liverpool, Bristol and Warrington, and to a less extent in Leeds, Manchester, and London. In Scotland the manufacture is principally carried on at Dunbarton, Glasgow, Leith, Haddington, and Ayr. The Irish manufactures are but trifling: the principal seats are Dublin, Cork, Lisburn, and Waterford.

It is difficult to form an estimate of the value of glass manufactured annually in the United Kingdom. Mr. M'Culloch believes it may be taken at about 2,000,000*l.*, and the number of workmen at about 50,000.

The following are the quantities of glass for the United Kingdom, which paid duties for the years 1838, 1839 and 1840:—

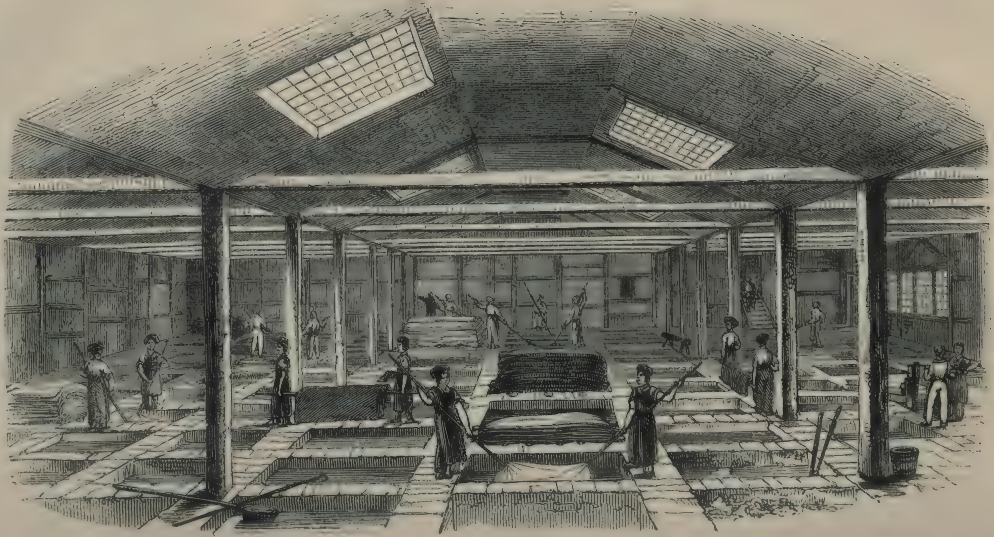
GLASS.	1838.	1839.	1840.
	Cwts.	Cwts.	Cwts.
Crown	147,553	136,712	146,838
Flint	98,897	104,955	104,882
Plate	25,813	28,413	33,623
Broad	6,575	8,514	9,051
Bottle	451,419	485,166	525,720

The following are the gross amounts of duty during the same periods:—

GLASS.	1838.			1839.			1840.		
	£	s.	d.	£	s.	d.	£	s.	d.
Crown . .	542,257	5	6	502,416	12	0	556,951	8	5
Flint . .	92,303	17	2	97,958	0	0	101,035	19	7
Plate . .	77,439	0	0	85,239	0	0	104,119	11	6
Broad . .	9,862	10	0	12,771	0	0	13,916	11	0
Bottle . .	157,996	13	0	169,808	0	0	189,943	4	10

An inquirer into the effects of a particular trade upon the health of the operatives, is very apt to infer evils which really do not exist. Experiencing in his own person the inconveniences of a new situation, he believes that men so circumstanced during a great part of their lives, *must* be affected with serious disorders. The high temperature to which glass-workers are accustomed, does not appear to have any

very injurious effect. The ordinary temperature of a glass house is about 70°; but when the men approach the furnace, which they are constantly doing, they are exposed to a heat considerably above 100°. Many of them are generally bathed in perspiration from the effects of heat only, for the muscular labour is very moderate. They are subject to coughs and colds, and in warm weather they describe their employment as being "very weakening." But they seem to be cheerful and contented in their work; and, when temperate in their habits, attain the usual age of man. Many of them are, however, unfortunately addicted to drinking. Mr. Thackrah says that individuals among the most intemperate are known to take, sometimes, as much as two gallons of beer in the day. "A practice like this, though probably less injurious than in occupations where the heat is moderate, produces disorder of the digestive organs." With the exception arising from this habit, the men are in good health.



THE TAN-PITS.

THE

MANUFACTURE OF LEATHER.

THE manufacture of leather in this country ranks next in importance to that of cotton, and of wool; and is, perhaps, equal to that of iron. Nor need this excite surprise, for what substitute could be found for leather?—a substance at once durable and elastic; affording protection from wet, from cold, and from external injury; capable of being formed into innumerable useful articles, and susceptible of a high degree of ornament; entering into the structure of various engines and machines; supplying harness to our horses, linings to our carriages, and covers to our books. But the chief importance of leather arises from its value as an article of clothing; and the necessity for such a protection seems to have stimulated man in all ages, and in the most widely separated parts of the globe, to the invention of some method for preserving the skins of animals.

Hence, it is difficult to say anything respecting the origin of an art, which, being so necessary to the comfort and welfare of mankind, must have been practised at a very early period. The skins of beasts taken in the chase are, in their fresh state, tough, flexible, and elastic, and seem well adapted for clothing; but in drying they shrink, become horny, and are liable to putrefy by exposure to moisture. But the qualities of the skin, which adapt it so

admirably to the purposes of clothing, may be restored, and even rendered permanent, by placing it in solutions of certain vegetables which abound in almost every country. Skins may also be made incorruptible, by steeping them in mineral waters which contain iron or copper; and the same purpose is answered by rubbing in oil or fat, a practice which is clearly alluded to by Homer.

The object of these processes being to render soft and flexible, that which would otherwise be hard and unyielding, the skin thus transformed was called by our Saxon ancestors *lith*, *lithe*, or *lither*, (that is, soft, yielding,) from which the word *leather* is supposed to have been derived. The word to *tan*, and the French *tanner*, are from the low Latin, *tanare*.

VARIETIES OF SKINS USED IN TANNING.

Leather is prepared from the skins of animals by means of a peculiar vegetable substance, found in the bark of most trees, called *tannin*. It is also made by a preparation of alum and salt, as in the process of *tawing*; a third method is, by dressing in oil.

The skin or hide of an animal consists of three distinct parts placed one over the other:—1st, the *epidermis*, or cuticle, which is covered with hair or wool; 2d, the *reticulated*, or *net*-like *tissue;* and 3d, the *dermis*, or true skin, which is in contact with the flesh. This last is the only part which can be tanned; so that it is necessary to get rid of the two former before the process of making leather can be commenced. The true skin is a thick, dense, hard membrane, composed of fibres interlacing each other in a curious complex manner. It is not equally thick throughout its texture; the part which covers the mane, the back, and the rump, being much thicker than the parts covering the belly. This skin consists, chiefly, of a substance called *gelatine*, from its jelly-like appearance when in solution: it is an abundant

material in many animal matters; in the skin of the ox it is *indurated*, that is, hard. Gelatine is distinguished from albumen (of which the white of an egg chiefly consists,) by being easily dissolved in warm water; whereas albumen is made solid by heat. All animal matter which affords gelatine may be used in making glue.

It might be supposed, in consequence of the vast quantity of animal food consumed in England, that the shambles would afford an abundant supply of skins to the tan-yard; but the hides furnished by this country are by no means sufficient in quantity to meet the demands of the leather trade. Immense quantities of skins are annually imported from various parts of the world, and it may be interesting to notice, briefly, their varieties and sources.

All tanned leather is classed and known under two denominations, *hides* and *skins*. From these there are three kinds of leather tanned in England.

I. *Butts*, or *backs*; these are selected from the stoutest and heaviest ox-hides. The butt is formed by cutting off the skin of the head for glue, also the neck, the shanks, and a strip of the belly, on each side. The remaining central part, the *butt*, or *back* of the hide, is the thickest part, and is used for purposes where great strength is required.

II. *Hides*, or *crop-hides*, consist of cow-hides, or the lighter ox-hides; they are tanned whole, and form leather which is used for ordinary purposes.

III. *Skins* are used for all the lighter kinds of leather, as will be more particularly noticed in the following enumeration.

The hides of South America are in the highest repute; they are the produce of the half-wild cattle which pasture on the wide plains between Buenos Ayres and the Andes; hides are also imported from various parts of the continent, and also from Morocco, the Cape of Good Hope, &c. In the year 1829,*

* In the year 1830 the duty on leather was wholly repealed.

286,416 cwt. of hides were imported, of which 166,400 came from South America, 24,000 from North America, and the remaining 66,000 from Russia, Denmark, Germany, and the Netherlands.

The *butt*, or *back*, of the ox-hide forms the stoutest and heaviest leather, and is used for the soles of boots and shoes, for most parts of harness and saddlery, for leather trunks and buckets, hose for fire-engines, pump valves, soldiers' belts, and gloves for cavalry. Formerly, when the use of metallic armour was on the decline, its place was taken by a very thick pliant leather made from the hide of the urus, or wild-bull, at that time plentiful in the forests of Poland, Hungary, and some parts of Russia. This animal was commonly called the *buffe*, whence originated the term buff-leather. The Russian Company, chartered by Henry VIII., was obliged to import a certain number of buffe-hides, to be manufactured for military purposes. Real buff-leather was pistol-proof, and would turn the edge of a sword. During the civil wars, in the reign of Charles I., it was in great request, but it afterwards declined. The hides of the real buffalo of Italy were also imported for the same purpose; but the modern buff-leather is made from cow-hide, and is used for little else than soldiers' belts.

Bull-hide is thicker, stronger, and coarser in its grain than that of the *cow*. The hide of the *bullock* is intermediate between the two. *Calves' skin* is thinner than cows', but thicker than most other skins employed. Leather is prepared from it for the bookbinder, by the process of tawing; but the greater part of the supply is tanned, and then curried for the upper parts of shoes and boots.

Sheep-skins are supplied, chiefly, by the home markets, but many thousands are imported from the Cape of Good Hope, and are considered superior to those of England, from which they are easily distinguished by the greater width of the skin that covers the tail. They are simply tanned, and em-

ployed for various purposes for which a thin cheap leather is required; such as for common book-binding, leathering for bellows, whip-lashes, bags, aprons, &c. They also form the cheaper kinds of wash-leather, for breeches, gloves, and under-waistcoats; as also coloured and dyed leathers, and mock morocco used for women's shoes, for covering writing tables, stools, chairs, and sofas, lining carriages, &c.

Lamb-skins are also, chiefly, of home produce; but they are largely imported from the North of Italy and Sicily. They are dressed white, or coloured for gloves. In 1829, 1,497,000 lamb-skins were imported from Italy and Sicily, and 239,000 from Spain.

The skins of *goats* and *kids* form the best kinds of light leather. The great supply of the best kid-skins is from Switzerland and Tuscany, whence they are shipped chiefly at Leghorn. Goat-skins are principally obtained from the coast of Barbary and the Cape of Good Hope. They form the best dyed morocco of all colours. Kid-skins supply the finest white and coloured leather, for gloves and ladies' shoes. In 1829, 306,000 goat, and 106,000 kid-skins were imported. Of the former, 104,000 came from Barbary, 87,000 from the Cape of Good Hope, and 36,000 from France; and of the latter, 82,000 from the Italian ports, and 16,000 from Spain.

Deer-skins are, to some extent, supplied by our parks; but the principal supply is from New York and New Orleans; a few are sent from Canada, and some from India. *Antelope-skins* from the Cape of Good Hope are of good quality. In 1829, 120,000 deer-skins were sent from the United States, 1,780 from Canada, and 675 from India. They are all shamoyed, or dressed in oil, chiefly for riding breeches.

Shamoyed leather of sheep, goat, and deer-skins, was formerly a celebrated and lucrative branch of the leather trade in this country. It was employed chiefly for the breeches, white or dyed, worn by

persons who rode much on horseback. The English shamoyed leather was so excellent that it was not only worn by our own troops, but by the cavalry of Prussia, Austria, and most other German states. During the Peninsular war, however, it was discovered by the British commander that, in wet weather, the leathern garments fitted close to the skin, and, being longer in drying, chilled the men, and made them liable to rheumatic and other complaints. Woollen cloth was therefore substituted, and the example being speedily followed by Austria and Prussia, this branch of the leather trade speedily declined.

Horse-hide is used, to a limited extent. It is tanned and curried for harness work for collars; and, being pared thin, is now much used for ladies' walking-shoes.

Dog-skin is thin, but tough, and makes good leather. The supply is entirely limited to this country, but has much fallen off of late years, being superseded as a material for thin dress-shoes by horse-leather, and tanned rat-skins. *Seal-skin* is inferior to that of the dog, but is employed for similar purposes. In 1829, 289,500 seal-skins were imported, the greater part of which were from Canada; but a large proportion of this supply is used as fur in covering caps.

Hog-skin furnishes a thin, dense leather, employed entirely for covering the seats of saddles. The general custom of cooking pork with the skin on, greatly limits the supply, which is chiefly from Scotland and Yorkshire.

VEGETABLE SUBSTANCES USED IN TANNING.

In the bark of most trees there resides a peculiar and remarkable substance, to which the name of *tannin* has been applied, from the circumstance of its uniting with the gelatine of skins, and thus

forming leather. The process by which tannin is obtained from vegetable substances need not be detailed, because the tanner never has to obtain it pure and separate from the woody fibres, &c., such process belonging to the scientific chemist. It will, however, be interesting to state the various proportions in which tannin exists in different vegetable substances, as ascertained by Sir Humphry Davy. In every 480 parts of each of the following substances, there exists a quantity of tannin, as shewn in the second column:—

White inner bark of Old Oak	72 parts.
— — — Young Oak	77
— — — Spanish Chestnut	63
— — — Leicester Willow	79
Middle bark of Oak	19
— — Spanish Chestnut	14
— — Leicester Willow	16
Entire bark of Oak	29
— — Spanish Chestnut	21
— — Leicester Willow	33
— — Elm	13
— — Common Willow	11
Sicilian Sumach	78
Souchong Tea	48
Green Tea	41
Bombay Caoutchouc	261
Bengal ditto	231
Nut Galls	127

Thus it will be seen how greatly the quantity of tannin varies in different vegetable products; and that it is by no means indispensable to employ oak in preference to any other vegetable bark; but the advantages of cheapness and abundance cause it to be generally preferred to other substances in the tanning of thick leather; although in some tan-yards, where other kinds of bark can be more profitably procured, they are preferred to oak. Most tanners, however, state that oak-bark surpasses all other barks in producing durable leather. The price of rough oak-bark varies from *5l.* to *7l.* per ton; but when freed from moss and the external core, the price becomes

as much as 9*l.* per ton. Large quantities of oak-bark are imported from the continent, but the quality is not equal to that of the English.

Of late years the bark of the larch has been much used in tanning. Large quantities of *valonia* and *terra japonica,* or catechu, and also a bean-pod called *divi-divi,* have been imported, and recently the bramble and hop-bine have been used for the same purpose. Valonia produces a leather of great solidity and weight, and of a greyish colour, with much bloom on the surface. It is said to resist water better than leather made from oak-bark, which is of a light fawn colour. Leather made from terra japonica is of a dark fawn colour, inclining to red; it is light and spungy, and not waterproof. In the preparation of thin leathers *sumach* is largely employed.

PREPARATION OF THICK LEATHER.

We will now visit the tan-yard, and trace the process of a skin from its raw or *green* state, until it is converted into leather.

When hides are received fresh from the slaughter-house, they are first washed in a stream of water; the horns are then removed and sold to the comb-makers; the ears and other projecting portions are cut off and sold to the glue-maker. Imported skins, which have been either salted or thoroughly dried for the purpose of preservation, require soaking in water for about ten or fourteen days.

The next operation is to get rid of the hair and scarf skin, for which purpose the hides are placed in oblong troughs or pits, containing lime mixed with water. In the course of several days the lime dissolves the hair sheath, and combines with the fat of the hide to form a kind of soap, which is easily washed off.

LIME PITS.—UNHAIRING HIDES.

When it is found that the hair can be removed, the *beam-man* places the skin upon a cylindrical table called the *beam*, and by means of a large two-handled knife scrapes off the hair, leaving what is called the *grain* of the skin. The hair is sold to the plasterer for mixing up with mortar.

The skin being once more washed, it is *fleshed*; that is, the beam-man passes a flesh-knife over the inner surface, for the purpose of getting rid of the cellular tissue and any remaining portions of fat or flesh.

The next process is that of *abating*, or *grainering*. The skins are put into a pit with a solution of dogs' dung; but if this is not to be had in sufficient quantity, its place is supplied by pigeons' dung, or by that of domestic poultry, or of sea birds. The excess of lime is removed by the lithic acid of the dung; and the ammonia formed by the putrefaction of the mixture, forms a soap with any remaining fat of the hide. The skin also becomes thinner by a portion of the gelatine being dissolved, and if left too long

in the mixture it would be reduced to a tender jelly-like mass: hence considerable care and judgment are required in regulating this part of the process.

The skins are now again worked on the beam, in order to get rid of all slime, dirt, &c., and are afterwards immersed for twelve hours in a very weak solution of sulphuric acid, called *sours*, for the purpose of *raising* or thickening the skin; the only use of this process, according to some, is to make the leather look thick when completed; but it probably assists the entrance of the tan into the pores of the skin, and may thus produce better leather, and shorten the process of tanning.

All these preparatory processes being completed, the actual tanning now commences. The tan-yard generally occupies a large extent of ground, and above it are lofts for drying the leather when it is tanned. The tan-pits* are formed in the earth, and lined with deal planks; they are oblong in shape, and from six to eight feet in depth. They are ranged in rows side by side, a space being left between them for the convenience of the workmen. The oak-bark is ground by a mill, attached to the yard, and the solution of bark, called *ooze*, is prepared in pits expressly reserved for the purpose. From these pits it is drained off into an ooze-well, whence it is pumped into shoots, and conveyed to any part of the yard. Since ooze of various degrees of strength is required, it is sometimes usual to employ a kind of hydrometer, called a *barkometer*, for measuring it. The instrument is graduated by the standard of pure water, and the ooze is said to be strong or weak, according as it rises above or sinks below the water-mark. But these indications are not always to be depended on, since the ooze dissolves a portion of the gelatine of the skin, and would hence appear to be strong when the tannin had been almost entirely exhausted. The more usual test of

* See Frontispiece.

ooze is a solution of pure gelatine, such as isinglass, which unites with the tannin, and forms a precipitate, more or less dense, according as the ooze is strong or weak. The strength of the ooze is also judged of with tolerable accuracy by its taste, which in strong oozes is highly astringent.

A number of hides being prepared by the processes already described, they are placed one by one, as open as possible, in pits containing nearly spent ooze. These pits are called *handlers,* because the skins are frequently taken out, and *handled* in the early stages of the process. The tannin begins to combine with the gelatine of the skin immediately the two are brought into contact, and hence a weak ooze is spent in a few hours; the skins are therefore removed to a pit containing a stronger ooze, and thus, for the first few weeks, they are shifted daily to oozes gradually increasing in strength. They are removed from the pits by two men, furnished with hooks; and are piled up at the side to allow the spent ooze to drain from them. Each pit contains several dozen hides, and one of the objects of this repeated *handling,* is to ensure the equal action of the tannin upon all the hides. In the course of a few months they are removed to other pits, called *layers,* where the ooze is nearly saturated, and the strength is maintained by a quantity of ground bark (sometimes of valonia) between every two hides. They remain in the layers undisturbed during some weeks.

The time required for tanning hides varies from nine to fifteen months; and for skins from three to five months. In the course of tanning, the whole of the skin or dermis disappears by successive formations of the compound of gelatine and tannin, on both sides of the hide, until all traces of the animal substance disappear. In an early stage a thick whitish line is seen on cutting across a hide: this is a portion of the skin itself; but as the process proceeds this also disappears, and the tanner knows that

the process is complete. The skins are then hung up in lofts to dry, and, once or twice during the drying, they are placed upon a cylindrical bench, and *struck* or smoothed with a square bar, the surface being occasionally wetted: the effect of this operation is to produce on the surface a yellow deposit called *bloom*, or *pitching*. This appearance is so much preferred by shoemakers, that if it were absent they would, probably, refuse to purchase the leather; it is, however, of no advantage, but rather the reverse, being in fact caused by a portion of the interior of the hide dissolved by the saturated ooze, to remove which from the interior to the exterior must prove injurious to the solidity of the leather. When the drying is sufficiently advanced, the hides are submitted to the action of a brass roller, about nine

"FINISHING" HIDES.

inches wide, loaded with from fifteen to thirty cwt. This is called *finishing*, and when complete, the hides are fit for the market.

It will be seen from these details that tanning is a very slow process. Many plans have been adopted for hastening it: such as forcing the ooze into the hide by hydrostatic or atmospheric pressure; but

these have failed, the leather so produced being pronounced to be of inferior quality; parts of the hide which are hard not having time to become perfectly saturated with the tanning liquor, an irregularity in the quality of the leather is the result. The very obvious method of increasing the strength of the ooze more rapidly than is customary, shortens the process, but the leather is hard and liable to crack. The same objection applies to warm oozes. The plan of employing strong oozes, from the commencement, fails, because solutions containing an excess of tannin dissolve the skin. Hence the old method continues to be practised, and to receive the sanction of eminent tanners and of scientific men. Sir Humphry Davy states that leather slowly tanned in weak ooze, appears to be better in quality, being both softer and stronger than when the process is hurried by employing strong ooze from the first.

There is, however, a new process for tanning, which has recently excited considerable attention. It is by Mr. Herepath of Bristol, who has patented the invention. That gentleman is of opinion that the great obstruction to rapid tanning is this:—the skins retain so much of the weakened ooze, that when placed in a stronger ooze, the latter cannot enter the pores already saturated with water or very weak ooze, except after weeks or months of maceration, during which time the exchange is being slowly made. In passing the skins from a weak to a stronger ooze they are therefore pressed between rollers, a pair of which is erected over each pit. The lower roller is about thirty inches in diameter, and is covered with horse-hair cloth; and the upper roller, which is loaded, is only about eighteen inches in diameter, and is covered with woollen cloth. For each pit fifty hides are formed into an endless band, by sewing them together with twine. Upon introducing this band between the rollers, the hides are successively lifted from the bottom of the pit,

strongly pressed by rollers, and then returned into the pit for a fresh supply of ooze. Mr. Herepath states, that each ooze becomes exhausted about two degrees of the barkometer in twenty-four hours, when it is pumped to the next pit of the series. It is said that by this process a strong hide may be completely tanned in six or eight weeks, and calf-skins and *kips* (the hides of young cattle) in from twenty to thirty days. The thickest hides, or *butts*, can by this process be prepared within four months of their being received in the tanner's yard; and the increase in the weight of butt leather, as compared with that made in the usual way, is stated to be as 34lbs. to 28lbs.

The opinions formed of the merits of this process are so contradictory, that the writer cannot venture to quote from them. The efficacy of the method must be tried by the quality of the leather; if it be superior or even equal to that produced by the old process, the new plan must be regarded as a national benefit; but if the leather be hard and brittle, the plan will, sooner or later, be abandoned.

It is generally the object of the tanner to make every hide or skin as heavy as possible, since he sells it by weight. The fair average weight of a good skin of uncurried leather is half the weight of the green hide, and the tanning is not considered successful if the weight be less.

Before taking leave of the tan-yard, the writer must refer to the heaps of spent bark which form a prominent feature therein. This refuse matter is applied to various uses. It is formed into cakes by pressure in iron moulds, and sold in London under the name of *turf*, as a cheap fuel. It also supplies the place of the more expensive article straw, thrown down in the streets of London opposite the house of a sick person, for the purpose of deadening the noise of carts and carriages. A third use is for the purpose of forming hot-beds; when collected in a heap, it slowly putrefies,

and forms a fine vegetable mould. Most of the pine-apples of this country are grown in a compost, into which the spent bark largely enters. After it has served its purpose in the hot-bed, it is transferred to the farmer, who finds it a useful manure.

CURRYING.

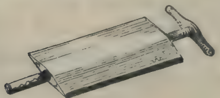
We will now transfer our skin of leather from the tan-yard to the currier's premises; where, by a series of mechanical operations, it will be transformed into a smooth, shining, and pliable skin, adapted to the purposes of the shoemaker, the coachmaker, the harnessmaker, &c. We will first trace the operations of the currier upon a tanned calf-skin.

The skin is first thoroughly soaked in water, in order to make it pliable; then taken to the beam, and shaved on the rough flesh side, whereby its thickness is considerably reduced, and the unequal surface brought to a tolerably smooth and even one. This is one of the most curious and laborious operations of currying.

The beam shewn in the accompanying figure consists of a strong frame of wood, supporting a stout plank faced with lignum vitæ, and made very smooth; this plank can be set at a greater or less inclination, and sometimes it is permanently fixed in an upright position. The knife, which is double-edged, is a stout rectangular blade, about twelve inches long by five wide; at one end is a straight handle, and at the other a cross handle, in the direction of the plane of the blade. The edge of the knife is brought up by means of a whetstone, and a wire edge is afterwards produced, and constantly preserved by means of a small steel tool, which the beam-man always has between his fingers while using the knife. The skin being thrown upon the plank, as in the figure, the

man presses his body against the skin, to prevent it from slipping; and holding the knife by its two handles, and nearly perpendicular to the leather, he

THE BEAM-MAN.



shaves off from the thick parts, and, after every shaving, passes a fold between his fingers, and thus ascertains the state of the skin with respect to evenness. When sufficiently reduced by shaving, the skin is again thrown into cold water, scoured, and extended. For this purpose it is placed upon a large stone table, to which the flesh side of the wet skin adheres, and is worked with a tool called the stretching-iron; this is a flat rectangular piece of iron, copper, or smooth hard stone, fixed in a handle, with the corners rounded off to prevent injury to the leather; the workman holds this tool with both hands, and, using plenty of water, scrapes the surface with a very strong pressure, especially at those parts

where lumps and inequalities appear. By the continued action of this tool the leather is extended or stretched, while at the same time the *bloom* is brought to the surface.

When the skin is thoroughly cleansed, and while yet in its wet and distended state, the process of *stuffing*, or *dubbing* (probably a corruption of *daubing)*, is performed. Both sides of the skin, but chiefly the flesh side, are smeared or daubed with a mixture of cod-oil and tallow, which is then well rubbed in by means of a brush, or a piece of old sheep-skin with the wool on. The skin is then hung up in a loft to dry; but as the water only evaporates, the greasy substances sink deep into the pores of the leather. In very moist weather the skins are stove-dried, the fuel for the stove consisting of leather shavings, and thus a most nauseous odour is diffused over the neighbourhood of the currier.

When the skin is sufficiently dry, it is *boarded*, that is, worked with an instrument called the *pommel*. The object of this is to bring up the *grain*, that is, to give the leather a *granular* appearance, and also to make it supple. The pommel is a piece of very hard wood, furnished with a strap on the upper side, for the insertion of the hand,* and grooved (like a crimping board), on the under side, which is convex. The leather is folded with the grain side in contact, and rubbed strongly on the flesh side with the pommel; this part of the process is called *graining*. It is then extended and rubbed on the grain side; this is called *bruising*. The skin is next taken to the beam and *whitened*, that is, the knife is passed lightly over it, whereby the flesh side is thoroughly cleaned and brought to a fit state for *waxing*,—a process which is never performed until the skin is required for immediate sale; for, at this part of our history, the currier stores his skins, because they are

* Hence the origin of the word pommel, from the French *paumelle*, because it clothes the *palm* of the hand.

brought to that state (technically called "finished russet") in which they can be best preserved for any length of time. Previous to waxing, the skin is boarded a second time. The first part of the process of waxing consists in laying on the "colour," or blacking, which is composed of oil, lamp-black, and tallow; the colour is rubbed in thoroughly on the flesh side, by means of a hard brush: it is then *black-sized;* that is, a coat of stiff size and tallow is laid on with a soft brush or a sponge, and well rubbed with a smooth lump of glass called a "slicker;" and lastly it receives its final gloss from a little thin size laid on with a sponge. The skin of leather now curried is called "black on the flesh," or "waxed," in contra-distinction to leather which is curried on the hair or grain side, called "black on the grain;" and which is chiefly used for the upper leathers of ladies' shoes; the former, or "waxed" leather, being employed for the upper leathers of men's boots and shoes.

The processes for currying leather on the grain side are similar to those already described, until we come to the process of scouring. *Copperas water*, that is, sulphate of iron dissolved in clean water, or in the water from the tank in which the skins have been soaked, is applied to the grain side of the skin while wet. The iron unites with the gallic acid of the tan, and thus produces an ink dye; the skin is then rubbed over with a brush dipped in stale urine, and when this is dry the stuffing is applied; it is rubbed over with copperas water on the grain side until it is perfectly black. The grain is then raised, and when quite dry, the skin is whitened, bruised again, and grained in two or three ways; a mixture of oil and tallow is then applied to the grain side, and the currying process is complete.

PREPARATION OF THIN LEATHER.

In addition to the tan-yard, properly so called, where the thickest and largest skins of leather are made, there are other establishments which contribute extensively to the immense demand for thin leathers; such as *white* and *dyed* leather for gloves, *morocco* of various colours and qualities for coach-lining, book-binding, pocket-books, &c., being an imitation of that prepared in Morocco, and other parts of North Africa; *roan* for slippers, &c.; a thin leather called *skiver*, used for hat-linings, and an infinite number of other purposes; and, lastly, *shamoy*, or *wash*-leather.

Of all these varieties, white leather alone is not tanned, but tawed. The difference between the two processes is, that the gelatine of the skin is combined with tannin in the one case; and in the other, with something which it imbibes from alum and salt, probably alumine. But, for either process, certain preparations are necessary, whereby hair, wool, grease, &c., are removed, and the skin, thoroughly cleansed, is reduced to the state of simple membrane, called *pelt*.

The preparatory steps vary, according as the skin is covered with wool, or short hair; the one being a valuable commodity, and the other comparatively worthless, its chief use being by the bricklayer to mix with mortar. The hair of kid and goat skins, &c., is therefore detached by immersing the skins in lime, as already described; but as this plan would injure the wool, a different method is adopted. The wool is usually detached from *sheep*-skins before they arrive at the tawers. This is done by the great dealers in sheep-skins, who are called *fell-mongers;* they receive the skins from certain factors, or salesmen, in the skin-market, by whom they are procured from the butchers. The lamb-skins of Italy are imported in casks with the wool on, so that the tawer adopts a

process for removing it similar to that employed by the fell-monger. They are first cleansed in water, and then scraped on the flesh side. They are then hung up in considerable numbers, in a close, dark, warm room, where they are *sweated*,—that is, putrefactive fermentation soon commences, a thick filthy slime appears on the surface, and the effect of this is so to loosen the wool, that it can be pulled off easily. Much care and judgment are required in regulating the fermentation of the skins, so that their texture be not destroyed. When the wool is removed, the fatty matters are got rid of by the powerful force of a hydraulic press; a large number of skins being piled up, a considerable quantity of fat is expressed; this is afterwards sold to the tallow-chandler. The skins are then worked at the beam; projecting flaps and rough edges are pared off for the glue-maker, and putrefaction is arrested by immersion in lime, for a space varying from two to six weeks. They are first put into a nearly exhausted lime-pit, and afterwards into a stronger one, and are frequently worked about with poles. When taken out they are well worked at the beam, the object being to get rid of a portion of the lime; and this is more completely effected by immersion in a fermenting mixture of dogs' or pigeons' dung, if the skins are to be tanned, and of bran and water if they are to be tawed, the acid of which unites with the lime, and further purifies and softens the skins. During the time that the skins remain in this mixture, they are occasionally taken out and worked at the beam, and are lastly washed in pure water. By such means the pelt becomes a thin extensible white membrane, and is fit for *tanning*, *tawing*, *dying*, *oil-dressing*, or *shamoying*. A brief notice of each of these operations will serve to convey some idea of the extent and importance of the manufacture of thin leathers.

TANNING WITH SUMACH.

The substance used in tanning goat, and other thin skins, is sumach, or the leaves, leaf-stalks, and young branches of the *Rhus coriaria,* and *Rhus cotinus,* shrubs which grow in Hungary, the Bannat, and the Illyrian provinces. They contain much tannin, and a small quantity of a delicate yellow colouring matter. It is said that all the leather made in Turkey is tanned with the bark of the *Rhus coriaria.*

When goat-skins are tanned with sumach, and then dyed on the grain side, they form what is called *morocco* leather; but an inferior morocco is prepared from sheep-skin. When the skins are in the state of perfectly clean white pelt, each skin is sewn by its edges, into the form of a bag, the grain side out; it is then distended with air, and a mordant of tin, or alum, is applied. The object of forming the skins into bags is two-fold, first, to economize the dye stuffs, (some of which are costly,) by dying the skins on one side only; and, secondly, to ensure a perfectly equable action of the dye, and also of the solution of sumach. If the colour is to be red, the skins are immersed in a warm cochineal bath; indigo is used for blue; orchil for purple, &c.; and they are worked by hand until uniformly dyed. For other colours the pelt is tanned before dying. The sumaching is conducted in a large tub, containing a weak and warm solution of sumach. A stronger solution is made in another vessel, and a portion of this, together with some sumach leaves, is poured into the bag, by means of a funnel, through an opening left for the purpose. This is diluted with a quantity of the nearly spent solution in the vat; each skin, after having received its share of the tanning liquid, is handed to a man, who blows into it, and fully distends it; he then ties up the opening, and throws the skin into the vat. About fifty skins are treated in this manner; they all float in the sumach-tub, and

THE SUMACH-TUB.

are moved about by manual labour, or by machinery, during three hours. They are then taken out, and piled on a sloping shelf by the side of the vat, the mutual pressure thus produced causing the sumach to escape slowly through the pores of the pelt. The bags are being constantly shifted by a man, who watches whether the solution escapes from the seams: if so, he secures them by a few stitches. They are next transferred to a second vat, containing a stronger solution than the first; and here they remain about nine hours, at the end of which time the tanning is complete. The skins are ripped open, rinsed, and drained. The colour of the fine red skins is finished in a weak bath of saffron; and, lastly, all the skins, of whatever colour, are stretched upon a smooth sloping board, and *struck*,—that is, scraped and rubbed out, until they become smooth and flat. Sometimes they are sponged on the grain side with linseed oil, in order to promote their glossiness in the subsequent process of currying.

The skins are then removed to a loft, and dried.

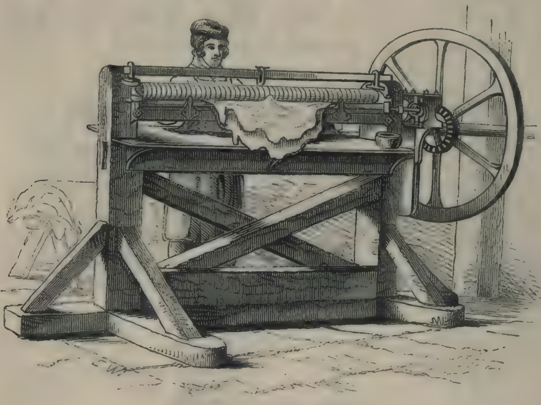
In drying they assume a horny texture, and are said to be *in the crust.* After this comes the process of currying, or finishing. The skins are again placed upon the smooth sloping board, and rubbed several times with the pommel, and also with a glass ball, cut with smooth sides upon its surface; this polishes them, and makes them firm and compact.

"FINISHING" THIN LEATHERS.

The grained, or ribbed appearance, peculiar to morocco leather, is imparted by a ball of box-wood, round the circumference of which are cut a number of narrow ridges. This is passed many times over the skin with a firm pressure, and its effect is not only to improve the surface of the skin, but also to add to its pliability and softness.

The preparation of an imitation morocco from sheep-skins, does not differ essentially from the processes just described; but there is one remarkable process applied to sheep-skins, which must be noticed. When they are in the state of pelt, they are *split;* that is, every skin is divided into two skins of the same size, but, of course, of only half the thickness of the pelt. This is effected by means of a very beautiful machine called the "skin-splitting machine." It consists of two rollers, the lower one of solid gun-

metal, and the upper one composed of rings of the same material; these cylinders are made to move slowly in opposite directions; and between them, but not in contact, is a knife, with a sharp cutting



SKIN-SPLITTING MACHINE.

edge, to which a rapid reciprocating motion is imparted. In order to *split* a skin, a man stands on the side of the machine, opposite to the knife edge, and, upon the lower or solid roller, spreads evenly the end of a skin or pelt; it is caught up by the rollers, and dragged forward against the edge of the knife, by which it is divided; one half going above, and the other below the plane of the blade. During the whole of the operation the man continues to adjust the skin upon the lower roller, the smooth solid surface of which gives support and stability to the skin, while the upper roller, being composed of moveable rings, adjusts itself to any unevenness of the membrane. In parts where it is thin, the rings are depressed; where it is thick, they are elevated; hence no part escapes the action of the knife, and no

holes are produced in either half. The men are furnished with gloves, to prevent their fingers being caught up by the rollers. About two minutes are occupied in splitting a sheep-skin, during which time the knife is moved to and fro nearly three thousand times. When three or four of these machines are at work in one room, the noise is deafening.

In order to show the precision with which this beautiful machine works, sheep-skins have been split into *three* parts of equal size; the grain side being used for skiver, &c.; the middle for making parchment; while the flesh side was transferred to the glue-maker. The divided skins, or skivers, are sumached in a short time, their thinness rendering the sewing up into bags unnecessary.

TAWING.

The preservation of an animal skin, by means of alum and salt, is called *tawing;* and the object is to employ such materials as will not interfere with the production of a pure white leather. In all the finer kinds of leather-dressing, the perfect purity of the pelt is of the utmost importance, for without it the subsequent operations would be thrown away; every particle of dirt, or lime, which is allowed to remain, appearing as a speck or a flaw. The purity of the water used for rinsing the skins, is also a point of great importance. At Messrs. Bevington's manufactory (which the writer was permitted to inspect) a sufficient supply of distilled water is obtained from the boiler to the steam-engine, which is made larger than usual for this express purpose.

Kid-skins, for the best kid-leather, and sheep, or lamb-skins, for an inferior sort, being reduced to the state of pelt, the first process in tawing, is to "give them a feeding" with alum and salt. About three pounds of alum, and four of salt, are used to one hundred and twenty middle-sized skins. The solu-

tion, together with the skins, is put into a drum, or tumbler, to which a rapid motion is imparted. The

TAWING DRUM.

action of the alum and salt upon the skins is not well-known, but it is supposed that alumine and gelatine form some definite compound, and that the salt serves to whiten the skins. After some time they are taken out, washed in water, and then put into bran and water, where they are allowed to ferment, till the superfluous alum and salt are removed, and the thickness produced by them is reduced. They are next transferred to the drying loft, stretched on hooks, and allowed to remain till fully dry. They now form a white, tough, brittle leather; but the glossy finish and softness of kid is imparted by a dressing, composed of twenty pounds of the finest wheat flour, and the yolks of eight dozen eggs.* This paste,

* This egg-dressing is indispensable in the preparation of white lamb and kid-leather. The eggs used for the purpose are imported from France and Flanders; and at the time of the writer's visit to Messrs. Bevington's factory, they had a stock of 60,000 eggs pickled in salt, which preserves them admirably.

diluted with water, is put into a drum, and the skins are made to rotate therein, when they so completely imbibe the egg-liquor, that scarcely anything more than water remains. This dressing is generally repeated before the skins are hung up to dry. But the softness and elasticity yet remain to be given. The skins are dipped into pure water, and allowed to remain for a few minutes; they are then spread out, and worked upon a board, and *staked* upon the *stretching* or *softening* iron. This is an iron plate,

"STAKING" TAWED LEATHER.

rounded over at the edge, mounted upon an upright beam, and fixed to a heavy plank, well secured in the floor. By these processes the skins are considerably extended in length, and all hard points and roughnesses removed. They are finally smoothed with a hot iron, and are then ready for the glover.

DRESSING IN OIL,

Consists in first soaking the skin in water, and then, by continued hard rubbing, forcing oil or grease into its pores. As the water evaporates, the oily matter combines in some way with the fibres of the skin; renders it permanently soft, and by keeping out the water prevents it from decay.

A process of this kind was formerly applied to the skin of the Chamois goat, and hence arose the term *chamois*, *shammy*, or *shamoyed*, as applied to the leather itself, and *shamoying* to the process. As this is the only kind of leather which, when dyed, will bear washing without the colour being materially injured, it is also called *wash*-leather.

Wash-leather is prepared, in this country, from doe's or sheep's-skin: and for the inferior kinds, the flesh side of sheep's-skin, as obtained from the split hide, is employed; the other half, or grain side, being tawed for skiver-leather. Indeed, it is common always to get rid of the *grain* before a skin is shamoyed; because, by doing so, the extensibility and softness of the skin are much increased. The grain is removed by an operation called *frizing*; that is, one end of the skin is wrapped over a pole, the grain side uppermost, and then the whole surface is scraped with a round knife, or with pumice-stone.

The grain being removed, the skins are placed in some bran liquor, and then wrung out; they are afterwards spread upon a table, sprinkled slightly with oil, and folded up in balls of four each, and beaten by a number of heavy wooden hammers in the *fulling stocks*. The heads of the hammers are covered with copper, and they work in a kind of trough, in which the skins are placed. After having been beaten for two or three hours, according to their texture and the state of the weather, they are taken out, exposed to the air, oiled and fulled several times,

until all appearance of greasiness has disappeared. They are next hung up in a warm room, when a kind of fermentation takes place, which opens the pores of the skin and promotes the combination of the oil. They are then scraped with a blunt concave knife, and scoured in a weak warm potash lye, in order to get rid of the uncombined oil. Having been washed in water, they are gently dried, smoothed, and made supple by the stretcher iron, or by passing them between rollers.

STATISTICS OF LEATHER.

In the year 1830, the duty on leather was wholly repealed; so that there are now no means of ascertaining the quantity produced in any one year. The yearly production, on an average of three years, ending in 1822, was 48,244,026 pounds. In this year the duty was diminished from 3*d.* to 1½*d.* per pound; and the average production of the next three years showed an increase of 30 per cent. The repeal of the duty and the increase in population have, doubtless, increased the consumption of leather to an equal, if not greater, extent. It has been calculated that the annual production, at this time, is about 82,000,000 pounds; the value of which, taking one quality with another, at 1*s.* 4*d.* per pound, amounts to 5,466,000*l.* It is supposed that the value of the leather forms only one-third of the finished articles, so that the ultimate value of the manufacture, in Great Britain alone, must be 16,400,000*l.* Some estimates are even higher than this, and make the aggregate value of leather goods to exceed 21,000,000*l.* per annum. "Nor will this amount appear excessive," says Mr. M'Culloch, "if we consider that there is only a very small proportion of the people, however poor they may be, who do not wear leather shoes or boots; that the use of leather gloves is general among all but the labouring classes; and that the harness of

horses used for pleasure, as well as those used for agricultural and other business operations, is made with this material, besides an endless variety of things in daily use, which will suggest themselves to every one's mind."

Some idea of the importance of the leather manufacture may be formed by considering the value of the shoes annually manufactured. It is generally supposed that the expenditure upon shoes may be taken, at an average of the whole population, at 10*s.* per annum for each individual, young and old, which, supposing the population to amount to nineteen millions, would give 9,500,000*l.* for the value of shoes only; but taking the value of shoes at only 8*s.* 6*d.* each individual, it gives 8,075,000*l.* for the amount. It has been supposed that the value of saddlery, harness, gloves, &c., is, at least, equal to that of shoes; but this estimate is thought to be too high.

The leather manufacture does not seem to exert any injurious action on the health of those engaged in it. Tanners are exposed to disagreeable odours, arising from putrefying skins combined with the smell of lime, or of putrid substances used in dressing them. The smell of the tan-pits is penetrating, but not by any means unwholesome; the men do not seem to suffer from any of these causes; and, although constantly exposed to wet and cold, they are robust, and disease is almost unknown among them.

In consequence of the odours diffused by tan-yards, they are generally situated at the outskirts of a town. During a long period, Bermondsey was the principal seat of the leather manufacture in England, on account of the Thames tide-streams affording an abundant supply of water. Although the Bermondsey manufactures are more extensive than ever, tan-yards are established near most of the towns of this country.

Curriers and leather-dressers sometimes suffer from the bent posture required by their work: this affects the head; but otherwise they are exposed to no injurious agent.

THE

MANUFACTURE OF PARCHMENT.

THE preparation of parchment from the skins of animals is closely connected with the manufacture of leather, and therefore requires to be noticed in this place.

Parchment derives its name from *Pergamus*, an ancient city of Mysia, where it is said to have been invented by Eumenes II., king of that place, (who reigned B.C. 197—159,) in consequence of the prohibition, by Ptolemy Epiphanes, to export papyrus from Egypt. It is, however, nearly certain that the invention must be referred to an earlier date, and that Eumenes was only an improver, or the patron of some improvements, in the manufacture at Pergamus.

As soon as men had invented written characters, they would naturally seek after the means of preserving some record of their most important transactions. Memorials of stone and of metal were long used for solemn occasions, while tables of wood were in more familiar use; leaves of trees and the inner bark were convenient substitutes for leather; but, perhaps, the most useful material was animal skin or membrane, which seems to have been used at a very remote period,

Some kind of animal membrane, or parchment, seems to be indicated in the "great roll" which the Lord commanded the prophet Isaiah to write "with a man's pen," (Isa. viii. 1,) and also the "roll of a book" in which Jeremiah wrote the words of the Lord, and which was cut with a pen-knife and cast into the fire, piece by piece, by Jehoiakim, king of Judah, as it was read in his presence, (Jer. xxxvi. 2,

22, 23), and a book described by Ezekiel as being written within and without with "mourning, lamentations, and woe." (Ezek. ii. 9.)

The ancient Persians are said to have written their records upon skins, and it is known that the Ionians employed the skins of sheep and goats for writing on, at a very remote period, understood to be many centuries before the time of Eumenes. The antiquity of parchment as a material on which the Holy Scriptures were transcribed, is shown also by an interesting discovery of the late Dr. Buchanan, who found in the record-chest of the Black Jews at Malabar, an Indian copy of the Pentateuch, written on a roll of goats' skins, dyed red. This ancient and beautiful manuscript was discovered in 1806, and is now deposited in the public library at Cambridge. The roll measures forty-eight feet in length by twenty-two inches in breadth. The book of Leviticus, and the greater part of the book of Deuteronomy are wanting; and it appears, from calculation, that the original roll measured not less than ninety feet. In its present condition it consists of thirty-seven skins, with one hundred and seventeen columns of perfectly clear and legible writing.

Although the word *roll* occurs several times in the Holy Scriptures, the word *parchment* is not mentioned more than once. (See 2 Tim. iv. 13.) The word in the original Greek, however, is *membrane;* and it is stated that the name *Pergamena* was not used until several centuries after the death of Eumenes.

We are not clearly informed of the ancient method of preparing parchment. In the seventh century it seems nearly to have superseded the use of papyrus, and also to have been used for strengthening and supporting written leaves of that fragile material. About the eleventh century the manufacture degenerated, from the circumstance, it is supposed, of writers preparing their own parchment. This practice is recommended by Hildebert, archbishop of Tours,

(born in 1054,) who, in a sermon on the "Book of Life," which he recommends his hearers to obtain, says—"Do you know what a writer does? He first cleanses his parchment from the grease, and takes off the principal part of the dirt; then he entirely rubs off the hair and fibres with pumice-stone: if he did not do so, the letters written upon it would not be good, nor would they last long. He then rules lines that the writing may be straight. All these things you ought to do, if you wish to possess the book which I have been displaying to you." About this period parchment was a very costly material, and hence arose the practice of paring or washing off the contents of an older manuscript for the sake of the material. Thus, many a beautiful poem or valuable history has been sacrificed to make way for a monkish legend; but ingenious and learned men having discovered means for deciphering the original writing, many valuable old classic productions have thus been preserved to the world. An old French writer, speaking on this subject, says:—"Some parchment has been restored three or four times, and has successively received the verses of Virgil, the controversies of the Arians, the decrees against the books of Aristotle, and, finally, the books of Aristotle themselves. Parchment is like an easy man, who is always of the same opinion as the last speaker." The practice of using parchment many times over was so common in the fourteenth and fifteenth centuries, that the diploma of the Imperial Notary of Germany expressly prohibited the use of *scraped* vellum in drawing deeds.

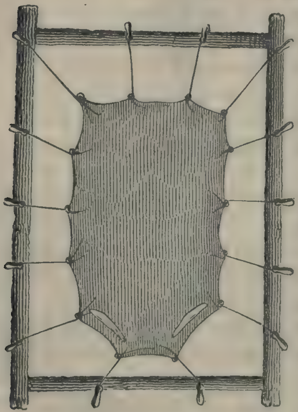
The invention of paper, in great measure, superseded the more costly vellum or parchment, although this substance was frequently used in printing. Dr. Dibdin states that almost all the known works before 1462 are printed upon vellum; the Psalters of 1457 and 1459 are upon vellum; and that of the Bible of 1462. More copies have been described upon vellum than upon paper.

PREPARATION OF THE SKINS.

Dr. Dibdin, in his *Bibliographical Decameron*, quotes a little book of Arts and Trades, which appeared at Frankfort in 1568, 12mo, with cuts, in which the parchment-maker is seen at work with tools and apparatus closely resembling those now in use; so that the processes about to be described have, probably, been followed during many centuries.

The skin of almost every animal is capable of being made into parchment; but that of the sheep or the she-goat is usually preferred. The finer kind of parchment, called *vellum*, is made from the skins of calves, kids, and dead-born lambs; the stout parchment, used for drum-heads, is made from the skins of asses, calves, or wolves, preference being given to the latter; the parchment of battledores is from asses' skin; and for sieves, the skin of the he-goat is preferred.

These skins are all prepared in the same way, or nearly so. Wool, hair, and fatty matters are got rid of by some of the processes which have been already described, and, when thoroughly cleansed, the skins are stretched in such a way as to prevent puckering, and to admit of their being easily worked. For this purpose a stout wooden frame, called a *herse*, is employed. It consists of four bars, perforated with a number of holes, in each of which is a wooden peg, which works in the same manner as the peg of a violin or a guitar. In order properly to stretch the skin, a number of pieces of twine are tied firmly to its edges, and,



THE HERSE.

to prevent them from slipping when the skin is strained tightly, each string is tied round a small wad or ball, formed by rolling up a shred of skin, and wrapping this into a small fold at the side of the skin which is to be strained. Sometimes skewers of several sizes are used: these are stuck into the edges of the skin, and the string is then firmly secured to them. The other extremity of each string is next passed through a hole in the side of the peg, and in turning this the string is wound round it, and thus the skin is gradually and equally strained. The pegs are first turned by hand, and afterwards with a key. The greatest possible care is required to prevent the formation of wrinkles.

SCRAPING.

The skin being properly strained, the herse is set up against the wall, and the skinner proceeds to scrape the surface with a semicircular double-edged knife, attached to a double wooden handle. This is sometimes called a *half-moon knife.* The skinner uses this knife with both hands, and pressing the edge against the skin, shaves off all fleshy substances. He next turns the herse so as to expose the grain side of the skin, and passes the knife over every portion of it. By this means dirt, slime, and a considerable quantity of water, are removed.

HALF-MOON KNIFE.

The next process is *grinding*. The skin is placed upon trestles, and sprinkled on the flesh side with finely powdered chalk or slaked lime, and then rubbed in all directions with a flat surface of pumice-stone. The grain side of the skin is next ground, but without the addition of chalk or lime. The knife is again passed over the skin, and the scouring with chalk and pumice-stone is repeated. This scraping with the knife is called *draining*, and serves to whiten the skin. The skinner then rubs fine chalk over both

GRINDING AND DRAINING.

sides of the skin with a piece of lamb-skin that has the wool on: this makes the skin smoother, and gives it a white down or nap, but great care must be taken not to scratch the surface. The skin is then removed to a covered shed to dry. In warm weather a moist cloth is occasionally applied to it, and the pegs are tightened. When perfectly dry, it is well rubbed with the woolly side of a lamb-skin, in order to get rid of the chalk. If any greasy matter should now be detected in the parchment, the skin is removed from the herse, and again steeped in the lime-pit for several days; but if the result is satisfactory, the

skin is removed from the frame by cutting it all round.

The skin is then passed to the *parchment-maker,* who stretches it upon a machine called the *sumner,* which is nothing more than a calf-skin mounted upon a frame. The tail of the skin being placed downwards, the parchment-maker then takes a sharp circular knife, and passes it over the outer surface, in an oblique downward direction, paring off about half of its thickness, and leaving it perfectly smooth; this is an operation requiring great flexibility of the wrist and considerable skill. The skin is scraped on the grain side only, and any remaining roughness is removed by rubbing with pumice-stone upon a kind of form or bench, covered with parchment, and stuffed with flock; this process leaves the parchment fit for writing on. If any small holes appear in the skin, they are stopped by cutting the edges thin, and pasting on small pieces of parchment with gum water.

Parchment is coloured green for binding. The following is a common method of imparting the colour:—In 500 parts of distilled water are boiled eight of cream of tartar, and thirty of crystallized verdigris; when the solution is cold, four parts of nitric acid are added. The parchment is first moistened with a brush, and the colour then spread evenly over the surface. Polish is given by white of egg or mucilage of gum arabic.

GLUE BOILING.

THE

MANUFACTURE OF GLUE.

GLUE is a preparation of gelatine in a dry state, and is made from the refuse of the leather-dresser and the parchment-maker. All the projecting flaps, the roundings, scrapings, and cuttings of skins, anything, in short, that contains gelatine, may be employed in the manufacture of glue. The following account of the process is chiefly derived from a visit to the works of Mr. Alfred Bevington, of Bermondsey, who has kindly permitted sketches of his machinery to be taken.

On receiving the refuse material from the leather-dresser, the first process is to make it clean and to get rid of matters which do not afford glue; the pieces are, therefore, immersed in a lime-pit, and when sufficiently steeped they are placed in baskets, and rinsed in a stream of water, and then placed on hurdles to dry. Whatever lime remains is converted into chalk by exposure to the air; and although lime would be injurious to the after processes, yet the presence of a minute portion of chalk is immaterial.

The gelatine is extracted from the pieces by boiling. For this purpose they are placed in a rope cloth, which is spread open within a large iron cauldron; a light framing of iron is contained within the cauldron to prevent the cloth from sticking to its sides. Water is then added, which is gradually brought to the boiling point; as the animal substances sink, fresh quantities are added, the whole being

occasionally stirred up and pressed down with poles. As the boiling proceeds, portions of the gelatine are taken out and set aside to cool, and when, on cooling, a clear mass of jelly is produced, the boiling is judged to be complete. The ends of the bag are brought together by means of cords, and by giving motion to the machinery over the cauldron the bag is slowly lifted out of it; the gelatine drains off, and this is further assisted by causing a portion of the bag to coil round the beam as shewn in the frontispiece. The solution of gelatine in the cauldron can, if necessary, be further evaporated by continuing to apply heat. The contents of the bag are boiled a second and a third time for making size, and when the solutions are too weak to produce either glue or size, they can be economically used instead of water. When nothing more can be extracted the refuse is sold to the manure-dealer.

CUTTING OUT AND DISTRIBUTING THE GLUE.

When the glue is thick enough it is drawn off into a vessel called a *settling-back*, and maintained at the temperature necessary to keep it liquid.

Here the solution deposits its solid impurities, and is further clarified by the addition of substances which vary according to the skill or judgment of the manufacturer. The glue is next run off into wooden coolers, which are about six feet long, one foot broad, and two feet deep, where, as it cools, it gradually hardens into a tolerably firm jelly. It is then cut out by a spade into square cakes, each of which is placed in a sort of wooden box, open in several slits or divisions to the back; the glue is cut into slices by passing a brass wire, attached to a kind of bow, along the slits. The slices thus formed are placed upon nets stretched in wooden frames, and removed to the glue-maker's field.

GLUE-MAKER'S FIELD AT BERMONDSEY.

The frames, as they are filled, are placed in piles with an interval between every two frames, so that the air may have free access to them. Each pile is covered with a roof to protect it from the weather. The glue is turned two or three times a day, for which purpose the roof is removed, and the uppermost frame placed on the ground. The cakes being turned one by one, a second frame is placed upon

the first, and the cakes on it turned in like manner; this goes on until a new pile is formed near the spot where the old one stood.

The drying of the glue is the most anxious and uncertain part of the manufacture. A material change in the weather may greatly injure it. If the air becomes very warm, the cakes may become so soft as to lose all shape, or they may even unite with the strings, so as not to be removed without dipping the net in boiling water; or they may even melt entirely, and flow out of the frames. On the other hand, a sudden frost may freeze the water in the glue and cause it to crack in all directions, rendering re-melting necessary. A thunder-storm sometimes prevents a whole field of glue from hardening; a fog will sometimes cause a general mouldiness; a wind too hot or too dry, by making it dry too rapidly, may render it unsightly and unfit for the market. Hence, it is important to select the most temperate season of the year for the manufacture.

When the glue is about three parts dry it is removed from the open air into lofts, where in the course of some weeks or months the solidifying is completed. During this time the surfaces become mouldy and otherwise soiled, they are therefore scoured with a scrubbing-brush in hot water, and set up to drain; and lastly, dried in the stove-room at an elevated temperature, which, when they are once solid, only serves to harden and improve them.

SCOURING.

Glue is usually judged of by its strong dark colour and freedom from cloudy and black spots when held before the light. The best glue swells considerably,

but without melting, on immersion in cold water, and renews its former size and properties by drying. In melting glue for use, it should be broken into small pieces, soaked for twenty-four hours in cold water, and then melted, very slowly, over a fire, keeping it frequently stirred; when prepared in this way, it becomes, when cold, a firm jelly, which requires only a little warming to fit it for use. If spread over wood with a stiff brush, pieces thus joined, will, in two or three days, be so perfectly connected, that they will as readily break in any other part as at the junction. Glue must not be used in a freezing temperature.

Other kinds of glue are prepared for particular purposes. Fish-glue, also called *isinglass* and *ichthyocolla,* is prepared from the skins and mucilaginous parts of fish. A strong compound glue is made by infusing during twenty-four hours common glue in small pieces with isinglass in a sufficient quantity of spirits of wine to cover the mixture. Heat is then cautiously applied, and, when melted, a quantity of powdered chalk is added, until the whole is of an opaque white. A strong glue, which will resist water, may also be made by adding half a pound of common isinglass to two quarts of skimmed milk, and evaporating the mixture to a proper consistence.

THE FILL-HOUSE.

THE

MANUFACTURE OF SUGAR.

HISTORICAL NOTICES OF THE SUGAR-CANE.

As sugar is most abundantly supplied by the sugar-cane, much interest has been excited respecting the early history of this plant. It has been supposed that the Hebrew word, which frequently occurs in the Old Testament,* and is sometimes translated *calamus*, sometimes *sweet-cane*, means the sugar-cane. It is mentioned for the first time in Exodus, where Moses is commanded to make an ointment with myrrh, cinnamon, *sweet calamus*, cassia, and oil olive. The calamus does not appear to have been a native of Egypt or of Judæa; for in Jeremiah it is mentioned as coming from a far country. "To what purpose cometh there to me incense from Sheba, and the sweet-cane from a far country?" It has been argued, that if the cinnamon mentioned in the passage of Exodus were true cinnamon, it must have come from the East Indies, the only country in the world from which it is obtained; and that it is, therefore, highly probable that the sugar-cane was exported from the same country.

Among the ancient writers of Greece, Herodotus alludes to the "honey made by the hands of men." Nearchus, Alexander's admiral, relates that "the reed in India yields honey without bees." Theophrastus describes three kinds of honey; one

* Exod. xxx. 23. Sol. Song iv. 14. Isa. xliii. 24. Jer. vi. 20. Ezek. xxvii. 19.

from flowers, another from the air, (referring probably to honey-dew,) and a third from canes or reeds. Other ancient writers are more or less precise in their mention of sugar, until we arrive at the time of the Roman Emperor, Nero, when Dioscorides uses the word *saccharum*, or sugar: his description refers to a species of sugar-candy, but he was evidently not aware of the mode of preparing it. He says: "There is a sort of concreted honey, which is called sugar, found upon canes in India and Arabia Felix: it is in consistence like salt, and it is brittle between the teeth, like salt." Seneca was also ignorant of the real character of sugar: he describes it as honey found on the leaves of canes, and produced by the dew or the sweet juice of the cane itself concreting. Pliny describes sugar as brought from Arabia and India: "It is honey collected from canes, like a gum, white, and brittle between the teeth; the largest is of the size of a hazel-nut; it is used in medicine only." Galen, who wrote in the second century, also speaks of sugar; and in the seventh century, Paulus Ægineta quotes an earlier writer, who describes sugar as "*the Indian salt*, in colour and form like common salt, but in taste and sweetness like honey."

It appears that, during a long period, the sugar-cane was confined to the islands of the Indian Archipelago, the kingdoms of Bengal, Siam, &c., and that the sugar was imported with perfumes, spices, and other merchandise, to the countries on this side of the Ganges. The traffic in sugar being lucrative, the Indians concealed the knowledge of the sugar-cane: they informed the merchants at Ormus that they extracted sugar from a reed, whereupon many attempts were made to obtain it from the reed-like plants of Arabia; but these were all unsuccessful.

The doubts respecting the real nature of sugar were not resolved until the year 1250, when Marco Polo visited the country of the sugar-cane. On his

return, the merchants, who had hitherto purchased sugar at Ormus, repaired to the country of its growth. They brought away the sugar-cane and the silk-worm, and from Arabia Felix these valuable productions passed into Nubia, Egypt, and Ethiopia, where sugar was soon produced in abundance, although its quality was very inferior, from ignorance of the means of preparing the juice. In 1420, the Portuguese introduced the sugar-cane from Sicily to Madeira; and, during the same century, it was probably carried from Spain to the Canaries. So successful was the cultivation, that the sugar of these countries was preferred to any other. The Portuguese also successfully transplanted the sugar-cane to the island of St. Thomas, and other islands on the African coast. Soon after the discovery of the New World, the Spaniards established sugar-works in Hispaniola, or St. Domingo: workmen were sent from the Canaries to manufacture the sugar, and the cane flourished so well, that its produce afforded a large revenue to the mother country. In 1641 the cane was transplanted from Brazil to Barbadoes, and thence to the other West India Islands.

For a long period the use of sugar in England was confined to medicines and feasts; and this continued until 1580, when it was brought from Brazil to Portugal, and thence to our country.

Mr. Porter remarks, that "The merchants who introduced the cane from India certainly neglected to bring, also, the necessary instructions as to the methods of preparing the juice; and the difficulties which the Arabian cultivators experienced, doubtless caused them to try the use of all kinds of ingredients for its purification, and to invent conical vessels for crystallizing and cleansing the sugar." The Venetians introduced the art of sugar refining into Europe, at the end of the fifteenth century. At first they imitated the Chinese, and sold the sugar which they purified in the shape of candy, cleaning and refining

the coarse sugar of Egypt three or four times over. They afterwards adopted the use of cones, and sold refined sugar in the loaf. This example was soon followed by the establishment of sugar refineries in all the commercial cities of Europe.

VARIETIES AND SOURCES OF SUGAR.

We are accustomed to associate sugar only with the sugar-cane, yet it is one of the most abundant productions of the vegetable world. It is found in a liquid state in most plants; it is manufactured from beet-root, from the sap of the maple, and other vegetable bodies; and this wide distribution of so valuable an article of food is one out of the many instances of the bounty of Providence in supplying our wants.

Of the numerous varieties of sugar, some can be made to ferment, others not; some can be formed into crystals, others not; but it often happens that two kinds of sugar are mixed, as in the sugar-cane, the juice of which yields the finest crystals, and also *molasses*, or *treacle*.* The size of the crystals, however, depends greatly upon the mode of treatment: when they are rapidly formed, as in common refined sugar, the crystals are small and confused; but when obtained by the slow evaporation of a strong solution, they are large and transparent, as in *sugar-candy*.

Sugar is the principal food of the vegetable world. It exists largely in the succulent parts of plants and seeds when they begin to shoot. It is formed in several kinds of seed in the process of *malting*, which consists merely in steeping seeds in water until they sprout. In the ripening of many fruits there is a

* An eminent French chemist is of opinion that the whole of the sugar furnished by the cane might be converted into crystals, molasses being formed, according to his view, by the boiling and other processes which the juice undergoes.

similar change. When palms are about to flower, the starch contained in their stems is changed into sugar. If plants are allowed to flower, the gum and sugar disappear from the roots or stems: this change applies to such common roots as the parsnep, carrot, beet, &c., as well as to the sugar-cane, maize, and other plants rich in sugar matter. The stems of grasses are also sweet at an early stage of their growth, when they are most nutritious and palatable to cattle, a circumstance which ought to regulate the time for making hay. In certain trees the starch formed in autumn is converted into sugar by the ascending sap in spring, and sugar is formed in considerable quantities from the sugar-maple. The sap of the birch-tree, on being fermented, yields an agreeable beverage, called *birch-wine*.

The juice of grapes furnishes a peculiar kind of sugar, called *grape-sugar*, which has been traced in many fruits, such as pears, peaches, cherries, melons, dates, figs, and the chestnuts which grow in warm countries. Grape-sugar is also formed in the nectaries of many flowers, and is collected by bees; hence *honey* belongs to this variety of sugar.

Grape-sugar can be procured from starch by the action of dilute sulphuric acid. *Lignin*, or *woody fibre*, or any substance containing it, can also be converted into sugar by the same means. If sawdust, linen-rags, paper, or other ligneous substance, be rubbed up with sulphuric acid, and the acid afterwards removed by adding an alkali or some powdered chalk, the ligneous body will be changed into a species of *gum*, which, being boiled for some hours in a weak acid, is gradually converted into sugar.* It has been well observed, that, "however clumsy and inconvenient this

* The conversion of old rags into more than their weight of sugar has been regarded as one of the marvels of modern chemistry; but the wonder ceases on comparing the ultimate composition of lignin, or woody fibre, (of which rags are only an example,) with sugar.

It appears, from Dr. Prout's experiments, that all the varieties of lignin are similarly constituted. 1000 parts of lignin consist of 500

process is in our laboratories, being, as we are, but Nature's journeymen, Nature herself carries on these transmutations with the most wonderful results, as we see in the ripening of fruits, when the hard woody texture gradually softens down into sweet and luscious pulp, as in the ripening of the pear, the grape, the strawberry, and, in short, almost all fruits."

The above varieties of sugar are granular or crystalline, and are all capable of undergoing the vinous fermentation. The only sugar which refuses to crystallize, but which can be fermented, is the molasses which remains after refining cane and other sugars, and this is largely used in the distillation of rum. *Sugar of milk* and *manna sugar* do not ferment. The former, sometimes called *Lactine*, is obtained by evaporating the whey of milk; the latter, also called *Mannite*, is contained in the manna which exudes from several species of ash: it is also found in the bark of the olive tree, in some species of pines, in the root and leaves of celery, in the bulb of the onion, in many kinds of sea-weed, and in couch grass. By long exposure to the air the juices of many plants, such as beet, carrot, &c. generate manna sugar.

Sugar is extensively employed to preserve animal and vegetable substances, such as meat, fish, fruits, jellies, and many medicinal substances; and in some cases is preferable to salt in not destroying the true flavour of animal food. The sugar which is naturally formed in many fruits is sufficient to preserve them, as in raisins, figs, and other dried fruits.

In temperate climates sugar is rather a luxury than a necessary of life; but in tropical countries it is extensively used as an article of food, and has been ranked inferior only to corn. Enormous quantities of sugar-canes are sent from the sugar islands to the markets of Manilla, Rio Janeiro, and

of carbon or charcoal, and 500 of water. 1000 parts of cane-sugar contain 421 of carbon and 579 of water. The different varieties of sugar contain variable proportions of carbon and water.

the surrounding countries. The crude plant is called by Dutrone, "the most perfect alimentary substance in nature," and this praise does not seem to be exaggerated when we consider its effects upon the negroes at the time of cane-harvest. "The time of crop in the sugar islands," says Mr. Edwards, "is the season of gladness and festivity to man and beast. So palatable, salutary, and nourishing, is the juice of the cane, that every individual of the animal creation, drinking freely of it, derives health and vigour from its use. The meagre and sickly among the negroes exhibit a surprising alteration in a few weeks after the mill is set in action. The labouring horses, oxen, and mules, though almost constantly at work during this season, yet, being indulged with plenty of the green tops of this noble plant, and some of the scummings from the boiling-house, improve more than at any other period of the year. Even the pigs and poultry fatten on the refuse."

In separating the sugar from the juice some of the nutritive substances are removed; and it should not be forgotten, that the praises bestowed on sugar by different writers on this subject apply to the fresh juice of the cane, and not to the crystallized sugar in use among ourselves.

THE MANUFACTURE OF SUGAR IN THE WEST INDIES.

Although the manufacture of sugar in this country consists chiefly in the production of a fine crystalline substance from a raw material, yet no account of sugar can be deemed complete without some account of the plant itself, its cultivation, and the processes adopted, in the countries where it flourishes, for extracting and preserving its juice.

The sugar-cane (*Saccharum officinarum*) is a jointed reed, varying in height according to the species, the character of the soil, and the mode of culture, from three and a half to seven feet, and sometimes from

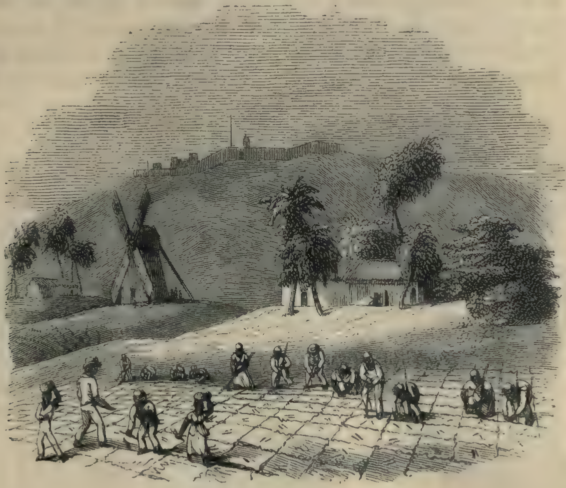
twelve to twenty feet. When ripe, it is of a fine straw colour, producing leaves or blades, the edges of which are firmly and sharply serrated, and terminating in an arrow decorated with a panicle. The joints in one stalk vary in number from forty to sixty, (and even eighty in the Brazil cane,) and the stalks rising from one root are sometimes very numerous. Every joint is furnished with a bud which encloses the germ of a new cane. The young shoot ascends from the earth like the point of an arrow; the shaft of which soon breaks, and the first two leaves rise to a considerable height.

The outer part of the cane is hard and brittle, but the inner consists of a soft pith containing the sweet juice, which at first has all the characteristics of unripe mucous fruits; it afterwards resembles, both in taste and smell, the juice of sweet apples; it gradually loses this, and takes the smell and taste peculiar to the cane.

The torrid zone is most favourable to the growth of the sugar-cane, but it may be cultivated as high as the fortieth degree of latitude. It will not flourish in a merely sandy soil; the best soil is the ashy loam of St. Christopher's, or a mixture of clay and sand, called *brick mould.* Due attention to manuring is of the utmost importance to the success of the cane.

The sugar-cane is propagated by cuttings, which multiply surprisingly. The slips for planting generally include two or three upper joints of the cane, stripped of leaves. These are planted in holes from fifteen to eighteen inches square, and from eight to twelve inches deep, at distances about two feet apart, and in rows three feet apart, spaces being left here and there, for the convenience of carting. Each hole is banked up round its margin with the earth thrown up by the hoe, and manure is put into it. Two or more cuttings are then placed lengthwise in each hole, and are lightly covered up. In about a fortnight the young sprouts appear: some of the earth heaped up round the hole is then put in, and as the plant

grows the remainder is gradually added. The young plants are carefully hoed, and all weeds removed. Off-shoots are likewise cut away, because they draw off nourishment from the plants.



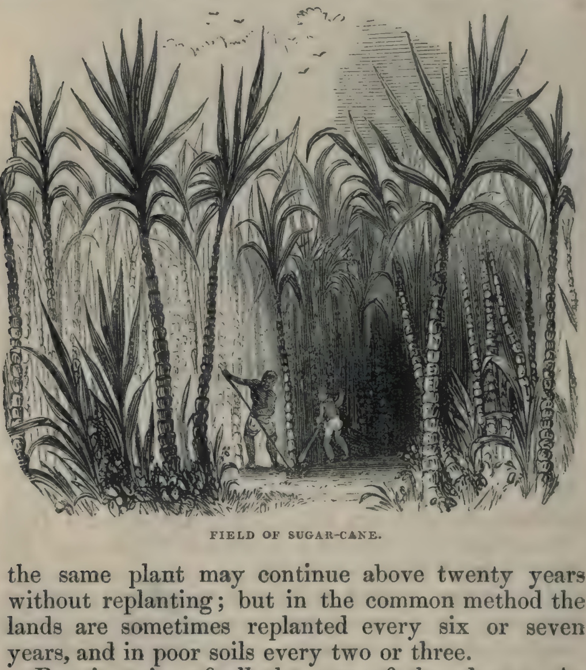
PLANTING THE SUGAR-CANE.

The canes which grow immediately from the planted slips are called *plant-canes;* but it is customary, in the West Indies, to raise several crops from the old roots, or *stoles*, as they are called; and the sprouts from these stoles are named *rattoons*, a corruption of the French word *rejetons* (sprouts).

The above method is subject to many variations, according to circumstances, among which may be mentioned the following: — The slips which are planted in August and September are managed as before till January, when the young plants are cut close to the ground, and the remainder of the mould is spread over the roots, which soon afterwards send forth a number of vigorous shoots of equal growth.

By this method the canes are not too rank in the rainy season, while they come to perfection in good time in the succeeding spring.

The best season for planting is between August and November, and the cane varies from ten to twenty months in arriving at maturity. If the soil be favourable, the canes planted at proper distances from each other, and the land carefully managed,



FIELD OF SUGAR-CANE.

the same plant may continue above twenty years without replanting; but in the common method the lands are sometimes replanted every six or seven years, and in poor soils every two or three.

But in spite of all the care of the planter, the sugar-cane is liable to many diseases. The most formidable is called *blast*. It is produced by myriads of little insects, invisible to the naked eye, which feed upon the juice of the cane, in search of which they

wound and destroy the vessels. Hence, the circulation being injured, the growth is checked, and it withers or dies. In some of the windward islands a kind of grub, called the *borer*, in dry weather, commits great ravages on the cane. Rats and ants do some mischief, but the latter are more annoying than destructive.

THE CANE HARVEST.

About the month of March or April the cane has attained maturity, as indicated by the skin becoming smooth, dry, and brittle; by the heaviness of the cane, and the juice being sweet and glutinous.

The following description of a field of sugar-canes, at two periods of its growth, is by an eye-witness:—

"A field of canes, standing in the month of November, when it is in arrow, or full blossom, is one of the most beautiful productions that the pen or pencil can possibly describe. It commonly rises from three to eight feet, or more, in height; a difference of growth that very strongly marks the difference of soil, or the varieties of culture. It is, when ripe, of a bright and golden yellow, and, where exposed to the

sun, is in many parts very beautifully streaked with red; the top is of a darkish green, but as it becomes more dry, from either an excess of ripeness or a continuance of drought, it is of a russet yellow, with long and narrow leaves depending, from the centre of which shoots up an arrow like a silver wand, from two to six feet in height, the summit having a plume of white feathers, delicately fringed with lilac."

In gathering in the canes, they are cut as near the ground as possible, as the lower joints contain the richest juice. One or two of the top joints, in which the juice is not sufficiently matured, are rejected; the remainder are cut into pieces about a yard long, tied into bundles, and conveyed immediately to the mill; for, if allowed to remain long, they would ferment and spoil.

As soon as the canes have arrived at the mill they are crushed between rollers, by which means all the juice is expelled. The rollers are hollow cylinders of cast iron, turned with the greatest care, and fluted with grooves of small depth. They are three in number, and measure from thirty to forty inches in length, and from twenty to twenty-five inches in diameter. They may be arranged either vertically or horizontally, and the middle roller, to which the moving power is applied, turns the other two by means of cogs. The canes are twice compressed between these rollers; for, having passed through the first and second, they are turned round the middle one by a circular skreen, called the *dumb returner*, and forced back through the second and third, an operation which squeezes them completely dry. The cane-juice is received in a leaden bed, and thence conveyed to the boiling-house. The rind of the cane, called *cane-trash*, serves for fuel to boil the juice; and it is also valuable as manure.

The fresh juice is thick, and gummy; of a dull grey, olive, or olive-green colour, and of a sweet balmy taste. It contains numerous solid particles of

the cane, most of which can be separated by filtering or by settling. The juice is so fermentable, that, in the climate of the West Indies, it would begin to turn acid within twenty minutes after leaving the mill, unless promptly boiled, and the sugar separated.*

The juice is quickly conveyed into large flat-bottomed coppers, or open pans, called *clarifiers,* which commonly contain from 300 to 400 gallons each. A fire is placed under each vessel, and

THE BOILING-HOUSE.

a syphon, or stop-cock, is supplied for drawing off the liquor. When the clarifier is filled with juice, a

* The juice, as it flows from the mill, contains, on an average, eight parts of pure water, one part of sugar, and one part of coarse oil and mucilage, with a portion of essential oil. The object of the subsequent operations is to separate this one part of sugar. In St. Vincent one pound of sugar is obtained from each wine-gallon of the best cane-juice; twenty gallons of juice, of middling quality, afford only sixteen pounds of sugar; and when the juice is watery, twenty-four gallons are required to produce the same quantity of sugar. Peligot says that out of every ten parts of juice nearly two parts are sugar, and that if more scientific methods of separating the sugar were adopted, little or no treacle would be produced.

small quantity of lime, called *temper*, is added, the object of which seems to be to correct acidity, and also, by rendering the solid impurities insoluble, to cause them to be thrown up into the scum. As the liquor becomes hot, this scum rises to the surface, and shortly before the boiling point is attained it forms blisters, and breaks into white froth. The fire is then extinguished, and the liquor allowed to repose during one hour, when it is carefully drawn off without disturbing the scum, which sinks unbroken, and is removed from the clarifier before another charge of juice is added. In this process, if the juice were allowed to boil, the scum would be broken up, and reabsorbed by the liquor.

The clarified juice, which is of a clear bright yellow wine colour, is next removed to the largest of a series of evaporating pans, which are placed over a large stove, heated by a fire at one end. Here the juice is suffered to boil, and the scum, as it rises, is carefully removed, lime-water being occasionally added if the juice is not clear. When sufficiently reduced in bulk by evaporation to be contained in the second or middle-sized pan, the juice is transferred, and the boiling and scumming repeated until it is sufficiently reduced to be contained in the third or smallest pan, called the *teache*. In this vessel it is boiled down to a thick syrup, which, on cooling, will *granulate*, or separate into grains of sugar. The required consistency is ascertained by taking a small portion of the syrup upon the thumb, then bringing the fore finger in contact with it, and again separating them, noting the length to which a thread of syrup can be drawn before it breaks: if this extends to about half an inch in length, the sugar is judged to be fully boiled. This trial by the *touch* is supposed to give the name of *teache* to the last evaporating pan.

The syrup is next laded or *skipped* into shallow wooden boxes, called *coolers*, each capable of containing about a hogshead of sugar. There the sugar

soon *grains*, that is, it forms into a soft mass of crystals imbedded in molasses, which are the uncrystallizable part of the sugar. The molasses are separated in the *curing-house*, to which the soft sugar is next removed. This is a large building, the lower part of which is lined with lead, and forms the molasses reservoir. Over this, on an open framing of joists, are placed the sugar-hogsheads, called *potting-casks*. In the bottom of each cask are bored several holes, an inch in diameter, into each of which is placed either a plaintain stalk or a crushed cane of sufficient length to reach the top of the hogshead. The soft sugar is then removed to these casks, and the molasses gradually drain away through the spongy stalks or canes, leaving the crystalline portion tolerably dry. In about three weeks it is fit for shipment. A further drainage of molasses takes place subsequent to shipment, amounting, it is said, to no less than 12 per cent.

Such is the *raw*, *brown*, or *muscovado* sugar of the West Indies, which is used for domestic purposes, and also by sugar-refiners in making *white* or *loaf* sugar. But there is another kind, very common on the continent, called *Clayed* or *Lisbon* sugar, the produce of the Island of Cuba, the Brazils, and other places. The cane-juice is prepared much in the same way as in the West Indies, until it arrives at the coolers, when, instead of being transferred to hogsheads, it is placed in conical earthen moulds, called *formes*, or *pots*, each of which has a small hole at the point. These holes being plugged up, the moulds are placed, with the point downwards, into earthen jars. The moulds are then filled with syrup, and allowed to repose during fifteen or twenty hours. The plugs are next taken out, and the uncrystallized syrup allowed to flow out. The sugar is then pressed down, and the space filled up with powdered white sugar; this being also well pressed down, a quantity of *clay*, mixed with water, is placed upon the sugar, and the moulds are removed to empty pots. The

moisture from the clay, filtering slowly through the sugar, carries away the colouring matter and the remaining portions of the uncrystallized syrup. The clay having parted with its moisture is taken off, and renewed several times during about twenty days, when the process is complete. The loaves are then taken out of the moulds, dried gradually in a stove, and afterwards each loaf is divided into three portions: the base of the cone being white, the middle yellow, and the small part brown; these are crushed into coarse powders and packed separately in hogsheads.

MANUFACTURE OF SUGAR IN THE EAST INDIES.

Several varieties of sugar-cane are cultivated in the East Indies, and the sugar is manufactured by two classes of persons,—the *Ryots*, who cultivate the cane, extract the juice, and boil it down to a thick syrup; and the *Goldars*, who convert the syrup into sugar. The whole of the apparatus used in the processes is very rude and imperfect, and not necessary to be described. The syrup prepared by the ryots is generally called *goor*, and is of various qualities, one of which, in common use for making sugar, is called by the English settlers, *jaggery*. This is produced by first straining the juice, to separate the coarser matters, and then boiling it in a row of earthen pots, placed in mud walls, and lastly, completing the boiling in an iron vessel. When the juice is sufficiently thick, it is poured into earthen pots, where it has much the appearance of honey. But if not intended for the refiner, a little quick-lime is added during the boiling, which enables it to be formed into cakes or lumps, and these are used for domestic purposes, in the same manner as the brown sugar of the West Indies.

The Goldar, who refines the sugar, separates much of the molasses, by placing the jaggery in coarse sack-cloth

bags, and subjecting it to pressure (a process which has been patented more than once in England). After this the sugar, which is called *shucker*, or *khand*, is boiled in an alkaline solution, to which a quantity of milk has been added. This is continued as long as any scum rises; it is then evaporated, and sometimes strained, and placed in earthen pots made wide at the top, and terminating at the bottom in a perforated point, which, at first, is plugged with the stem of a plaintain leaf. After being allowed to remain a few days, the holes are opened, and the molasses allowed to drain off. The sugar is improved in quality and colour by covering it with the moist leaves of some succulent aquatic plant, which is equivalent to the process of claying just described. After some days the leaves are taken off, and the upper layer of the sugar, about half an inch thick, which is most purified, is removed and dried in the sun; fresh leaves are applied to the remainder, and thus, by repetitions of the process, occupying from seventy-five to ninety days, successive layers are refined and removed until the whole is complete. This kind of sugar, called *chenee*, is imported into this country.

BEET-ROOT SUGAR.

The botanical name for beet is *Beta*, so called from a fancied resemblance of the plant, while bearing seed, to the form of the Greek letter β. The Germans call it *mangold-wurzel*, or *mangold* root, but it is usually pronounced *mangel-wurzel*, which means *scarcity-root*. By a strange contradiction, the French call it *racine d'abondance*, or root of plenty, and also, *racine de disette*, or root of scarcity. There are several varieties of this plant, and one variety, which is extensively grown for the purpose of feeding cattle, is sometimes called *field-beet*.

In the year 1747, a German chemist, named

Margraff, discovered that the white beet-root yielded a larger supply of sugar than any other European plant. The subject excited some attention in Germany, and was then forgotten until the commencement of the present century, when Napoleon's scheme for injuring the prosperity of Britain, by excluding British colonial produce from France, rendered some method necessary for supplying the French with sugar. Among other plans, that of extracting sugar from beet-root was adopted and encouraged by the government. The plan succeeded, but the cost of the sugar was so enormous, that, on the establishment of peace, in 1814, the ports of France were again opened to West Indian produce, and the beet-root manufacture soon ceased to be carried on. It may be interesting, however, in a work of this nature, to detail briefly the processes adopted under the direction of the best French chemists of the time, for conducting the manufacture.

The first operation is, to clean the roots, which is generally done by scraping with a knife. They are next rasped, and reduced to a pulp by means of a cylinder of tinned iron, from the surface of which narrow plates of iron project, so as to form a series of cutting teeth: the roots are pressed against these plates by a slanting box attached to the frame, on which the axis of the cylinder turns. The pulp is received into a vessel lined with lead, placed below the cylinder. Two cylinders are sufficient to grind down two and a half tons of beet in two hours. This part of the process should proceed rapidly, because the pulp is liable to ferment and spoil. As the pulp is ground it is taken out and placed in strong canvass bags, and the juice, or *liquor*, as it is called, is expelled by strong pressure. The pulp, after being stirred up, is pressed a second, or even a third time. The liquor is allowed to flow immediately into a copper, and heated to 178° Fahr. The strength of the liquor is ascertained by a sac-

charometer, called a *pèse-liqueur*; a mixture of lime and water is then stirred in, and the heat increased to boiling point. A thick glutinous scum rises to the surface, and when clear bubbles rise through this scum, the fire is put out. The scum hardens on cooling, and, the sediment being deposited, the liquor becomes clear and of a light straw colour. The scum is then carefully skimmed off, and the liquor remaining in it pressed out. A cock, placed about five inches above the bottom of the boiler, is next opened, and the clear liquor drawn off. A lower cock lets out a further portion until it appears cloudy: the remainder is boiled again with the liquor extracted from the scum. The clear liquor is then evaporated in a wide shallow boiler to a certain degree of thickness, as indicated by the *pèse-liqueur*, when animal charcoal is added. The boiling is continued until a regular syrup is formed, after which it is strained through a linen bag. This syrup is again boiled and skimmed until it is sufficiently concentrated for crystallizing, which is judged of by the *touch*. The syrup is then transferred to a cooler, and, as soon as crystallization commences, it is beaten up and laded into sugar-loaf moulds, which are removed to the coolest part of the premises. As crystallization proceeds, the crust formed on the surface is frequently broken, and the whole is stirred until the crystals are collected in the centre; it is then left undisturbed. In three days the pegs at the points of the moulds are taken out, and the molasses allowed to drain off, which they do in about a week. White syrup is then poured over the base, which filters through the mass, and carries off much of the colouring matter. The remaining processes are similar to those described further on, under the head of "Refining."

When this sugar is refined, it is impossible to distinguish it, either by the taste or appearance, from refined cane-sugar, and hence arose the practice of smuggling large quantities of colonial sugar into

France, and selling it as beet-root sugar. Indeed, Chaptal, after an experience of twelve years, came to the conclusion that beet-root sugar does not differ from cane sugar, either in colour, taste, specific gravity, or crystallization. He found that 5 tons of clean roots yield about 4½ cwt. of coarse sugar, which produce 160 lbs. of double refined sugar, and 60 lbs. of inferior lump sugar; the remainder is molasses, from which a good spirit is distilled. The expenses of the manufacture, however, are so high, that, in a commercial point of view, beet-root sugar can never compete with cane sugar.

MAPLE SUGAR.

In the Philosophical Transactions of the Royal Society, for 1720, is a paper by Paul Dudley, entitled "An Account of the Method of making Sugar from the Juice of the Maple-tree in New England." This is the earliest notice of a method of procuring sugar, which is still practised in many parts of the United States. During the American revolutionary war, the supplies of West India sugar being for the most part cut off, maple sugar was made in large quantities.

The sugar maple (*Acer saccharinum*) grows plentifully in the United States. Its sap is obtained during the months of February, March, or April, according to the season, by boring holes in the trunk in a direction inclining upwards. The south side of the tree is preferred for boring, and the holes, two or three in number, are made at a height of about twenty inches from the ground. The holes are made to penetrate about half an inch into the alburnum, or white bark. A tube of elder or sumach is inserted into each hole, and the sap trickles from this into a vessel placed beneath. The quantity yielded by a tree varies considerably, but the most favourable

season for collecting it is when the difference between the heat of the day and that of the night is greatest. From two to three gallons are considered as the daily average afforded by a single tree; but as many as twenty gallons have been obtained from one tree in one day. The sap is very liable to ferment, and must therefore be boiled down speedily. This is done by a rude apparatus erected in the encampment of the sugar makers. The syrup is evaporated to about one-third of its original bulk, the scum being removed. A small quantity of butter, or fat, is thrown in during the last boiling. The molasses are separated in an imperfect manner by filtration. The sugar is said to be equal to cane sugar, and cannot be distinguished from it in the refined state.

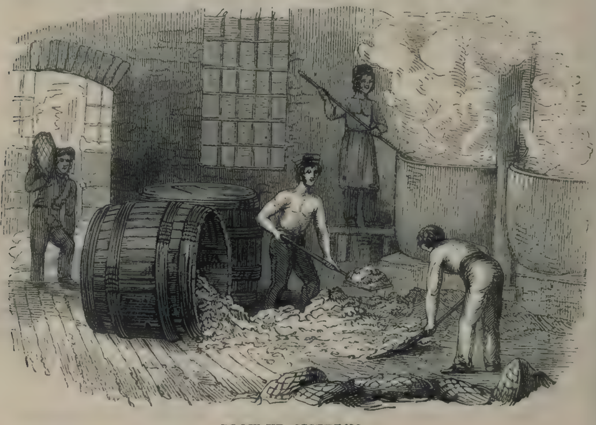
SUGAR REFINING.

The processes by which raw or brown sugar is converted into white sugar are of a striking and interesting character. Of late years they have been subject to considerable improvement, and they now partake largely of the scientific character of our most important manufactures.

The principal sugar refineries of London are situated in Whitechapel and its neighbourhood: most of them are extensive buildings, each consisting of seven or eight stories; the rooms, or *working-floors*, as they are called, present a singular appearance. Each floor is paved with stone, is of small height, and the ceiling is formed of brick arches, supported on iron pillars; the object being to render the building fire-proof and of great strength, and also to provide an extensive surface for arranging the sugar in the different stages of the process. A square opening is left at the side of each floor, over which, in the top floor, is a crane, for the purpose of removing the sugar as occasion requires.

The reader may perhaps be able to form a tolerably accurate idea of the art of sugar refining, from the following attempt to trace the sugar from its raw to its refined state. The description applies to an extensive refinery at Whitechapel (Messrs. Fairrie's), which, in company with an artist, the writer was privileged to visit.

Sugar from the West Indies is packed in hogsheads, and that from the East Indies in canvass bags, covered



BLOW-UP CISTERNS.

with matting. These are received into the first floor of the refinery, situate a little above the street, where they are broken open and unpacked by the side of a large circular vat or cistern, which is pouring forth clouds of steam, and filling the floor with an oppressive sickly vapour. In this cistern the sugar is first mixed with water, with the addition of a small quantity of lime-water and bone black. Heat is applied by means of steam, which issues from a number of small copper pipes contained at the bottom of the vessel, and from this method of applying heat the vessel is called the *blow-up cistern*, the

steam forcing itself by its own pressure, or *blowing up*, through the mixture. The perfect solution of the sugar is promoted by stirring with long poles. Shortly before the liquid has attained the boiling point it is allowed to flow along a channel into a filtering apparatus, situated in the room beneath; on leaving which it appears as a clear reddish syrup.

The chief object of this process is to separate mechanical impurities, such as dust, dirt, &c. from the sugar. Until within a few years the process was conducted in a ruder and far less direct manner. The raw sugar, mixed with lime-water, was heated in a large open copper by a fire from below, and when warm a considerable quantity of bullocks' blood, technically called *spice*, was stirred in. The serum or watery part of the blood, (consisting chiefly of albumen, of which white of egg is a familiar example) becoming curdled by the heat, and entangling most of the impurities floating in the solution, raised them to the surface in the form of a thick scum, which was carefully removed. This process was sometimes repeated two or three times, with fresh quantities of blood, and from the scummings a low quality of sugar was afterwards obtained. The liquor being thus clarified, was filtered through a thick woollen cloth, and afterwards boiled in an open copper until sufficiently concentrated for graining. So imperfect was this method, that, in order to produce loaves of the finest quality, a second refining was necessary; the loaves first produced were broken up and re-dissolved, and clarified with white of egg; this being carefully skimmed off, a small portion of indigo was added, the effect of which was to neutralize the yellow colour of the syrup. These costly methods, which of course greatly increased the price of sugar, are now rendered unnecessary; for, in the modern process, a clear liquor is obtained without the aid of so offensive a substance as bullocks' blood, a portion of which generally became entangled with the sugar, and was not separated by crystallization.

The filtering apparatus now in use is arranged in an ingenious manner. It consists of square vessels of iron, about eight feet high, connected with cisterns above and below, and containing a number of twilled cotton cloth tubes, closed at their lower ends, but open at the upper ends, which are screwed into the floor of the upper cistern. Within each tube is a bag of cotton cloth, which, being considerably wider than the tube, hangs down in folds. About sixty tubes, thus arranged, are contained in each filter, so that by this means an extensive filtering surface is obtained; the liquor from above, having to

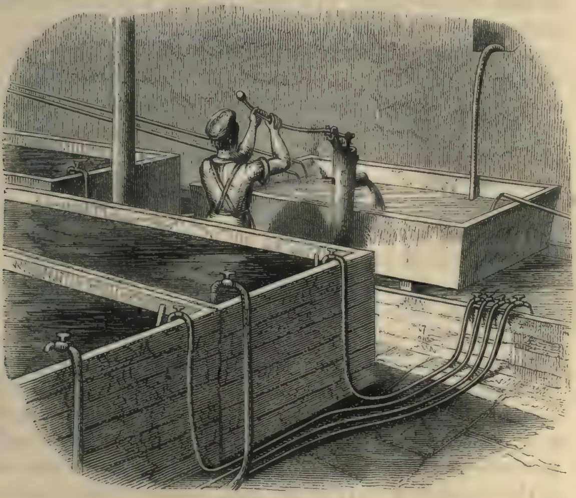
BAG FILTERS.

pass through the meshes of the cloths, is strained of most of its solid impurities, and a clear reddish syrup drops into the cistern below. The bags soon become clogged up, and are frequently removed for the purpose of being cleansed. A black viscid mud is scraped off, but, as this contains a portion of saccharine matter, it is again boiled and otherwise treated before it is transferred to the dealers in manure.

It is obvious that, in order to produce white

sugar, the syrup or liquor must be without colour. When it leaves the filters it is of a dark red colour, and to remove this is the object of the next process, the introduction of which is one of the great modern improvements in the art of sugar refining.

Chemists have discovered the existence of a remarkable attraction between animal charcoal and the colouring matters furnished by animal or vegetable substances. This kind of charcoal (or as it is sometimes called, *bone-black*, or *bone-charcoal*) is produced by heating bones to redness in a close vessel, or when covered over with sand. The bones lose about half their weight by being calcined; they are then pounded in a mill into a coarse granular state like gunpowder, in which they are fit for use.



CHARCOAL FILTERS.

The charcoal filter at Messrs. Fairrie's are oblong vessels, about five feet in height, furnished with a double bottom, the upper one being pierced

with holes and covered with cloth to prevent the holes being choked up and the particles of charcoal being carried away by the liquor. The charcoal is heaped up on this cloth to the depth of three feet, and the reddish liquor from the cistern above is allowed to flow in a gentle stream over the surface; it slowly sinks through the mass, gradually losing its colour, until it arrives at the space below, when it is colourless. A series of pipes and syphon tubes from the various "charcoal cisterns," as they are called, conveys the filtered liquor into reservoirs, whence it is pumped up to the sugar boiler in the room above.

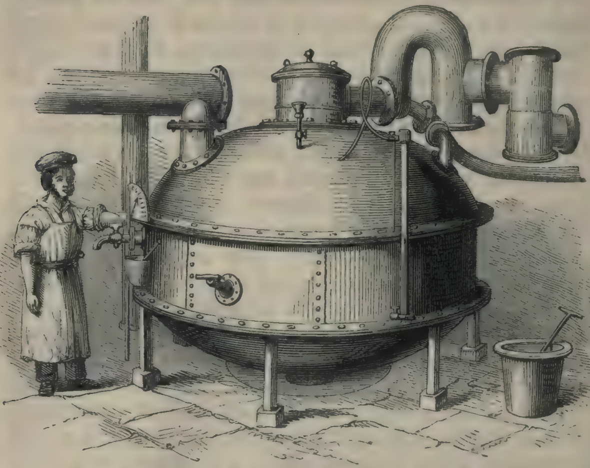
In the course of a few days the charcoal becomes foul and unfit for use. Water is passed through it to remove all saccharine matter, and it is then taken to the retort-house and re-calcined, a process which restores all its valuable properties.

The next process which the liquor undergoes, namely, the boiling preparatory to crystallizing, is one of the most important in the whole range of operations to which the sugar is subjected. By the old method the syrup was concentrated in open pans, standing over fires, and heated to 240° or 250° Fahr. This high degree of heat was very injurious to the sugar, for it changed a large portion of it into treacle, which had to be got rid of in the moulds. The method was also objectionable on account of its danger, and the difficulty of managing the heat. Many plans were adopted for heating the liquor, by passing steam pipes through it, or hot oil under it, but they were all superseded by the valuable invention of the Honourable Edward Charles Howard, now in general use under the name of Howard's vacuum-pan, first introduced in 1813. The principle of this invention rests on the fact, that the boiling points of all fluids are considerably lowered by placing them in vacuo. Thus, under ordinary circumstances, water boils at 212°, the pressure of the air, which is equal to about fifteen pounds on every square inch of surface,

preventing the rapid formation of vapour at a lower temperature; but if water, at the temperature of 90° or 100°, be placed under the receiver of an air-pump, and the air be exhausted, the water will boil rapidly and pass off in vapour. The object, therefore, which the inventor of the new method had in view was to collect a sufficient quantity of syrup in a closed vessel placed in connexion with an air-pump; then to remove the air, and apply a very moderate degree of heat, by which means the syrup could be boiled at a low temperature, and brought down to the granulating pitch. After numerous trials and failures the inventor was rewarded with success, and continued during several years to derive a large income from premiums paid by sugar refiners for permission to use the patent process. The patent having now expired, no restriction is placed upon its general use.

The vacuum-pan consists of a large copper vessel, about six feet in diameter, supported on legs, so that every part may be conveniently inspected. The lower part of the pan is double, for the purpose of letting in the steam which is used to heat the syrup: within the pan, in contact with the syrup, is a coil of copper pipe, through which also steam is passed. The bottom cavity, or *steam-jacket*, as it is called, is supplied with low pressure steam, but the spiral pipe is filled with high pressure steam, which is considerably hotter than boiling water, and greatly promotes the evaporation of the syrup. From the centre of the dome rises a neck, which, by means of a bent tube and other apparatus, connects the interior of the pan with the air-pump used for extracting the air and vapour. The interior of the pan is also connected by means of pipes with vessels containing the clarified syrup which may be situated in the upper stories, or in the charcoal-filtering room below. In the former case, the syrup runs down into the pan on turning a stop-cock in the pipe, and in the latter case it rises by atmospheric pressure, as

soon as a partial vacuum is formed in the pan. The pan is furnished with a barometer or manometer, for showing the state of vacuum, and also with a thermometer, for indicating temperature. There is also a cistern-pipe, for receiving any syrup that may acci-



THE VACUUM PAN.

dentally boil over; but the too rapid boiling, and also the danger arising from the pressure of the air on the outside, which might crush in the pan, are prevented by a safety valve, which admits air in case the exhaustion should at any time be made too perfect. There are numerous other minor details, which need not be particularized.

The pans generally contain each about 100 gallons of syrup, which yield about eleven cwt. of granulated sugar at every charge. Sometimes the pans are of larger dimensions. Dr. Ure mentions one in use at a London house, which works off eighteen tons of sugar-loaves daily.

The pans being properly charged, and steam

admitted within the steam-jacket and the coiled pipe, the air-pump is set in action, its moving power being supplied by the steam-engine of the establishment; the syrup soon attains a temperature of about 130°, when it boils, and throws off vapour of water, which is pumped off, and condensed in a vessel placed in the open air, over which a stream of cold water is constantly flowing. As the syrup becomes more concentrated, its boiling point becomes higher: the temperature is, therefore, gradually raised to about 150°, which is about 100° lower than would be required for open vessels. The attendant is enabled to watch the process by means of a very ingenious contrivance, called a *proof-stick*. This consists of a cylindrical rod, exactly fitting a hollow tube which enters the pan in a direction slanting downwards. The upper end of the rod is open; the lower end, which dips into the syrup, has a slit on one side of it, about half an inch wide. Within this tube is another shorter tube, which can be moved round in it through half a circle: near the lower end of this tube is a hollow which corresponds with the slit in the outer tube; and the upper end is connected with a handle. By making the slit and the cavity coincide, the latter is filled with sugar; then, by turning the stick round through half a circle, the slit is covered by the fixed tube, and the inner tube can then be withdrawn without allowing air to enter the pan.

THE PROOF STICK.

The sugar is tried by the *touch*, as already explained: the small crystals which appear in it are examined, and the moment the liquor has attained the granulating pitch, the connexion of the pan with the air-pump is cut off, air is admitted to equalize the pressure, and a plug at the bottom of the pan is opened, by means of a lever attached to it, when the whole of the syrup flows down a pipe into a receiver situated in the room below.

In our notice of the process of sugar-boiling in the West Indies, it was stated that, as soon as the syrup was boiled down to the point of granulation, it was transferred to a vessel called a *cooler*, the process of boiling in open vessels raising the liquor to so high a temperature, that cooling is absolutely necessary to crystallization. The introduction of the vacuum-pan has wrought a curious change; for, after the boiling is complete, the syrup is removed, not to a *cooler*, but to a *heater*, where it is raised to the temperature of 180° or 190°, the object being to make the syrup more fluid than the comparatively low temperature of the pan admits of, and also to prevent crystallization before the sugar is poured into the moulds; for, were this to take place, the colouring matter would be so imbedded in the mass of crystals, that no after treatment, short of re-melting, would get rid of it. Not only, therefore, is the temperature of the syrup raised, but men are employed with poles in beating and stirring it up, while it is being removed to the moulds.

The heater is a shallow vessel of copper, surrounded with an iron steam-jacket for keeping up the proper degree of heat. The syrup which flows into it from the pan is no longer a limpid, colourless fluid, as it was in the filter-cisterns; it is now exceedingly thick and viscid, and the process of boiling has concentrated the colouring matter, the molasses, and uncrystallizable parts of the sugar, to get rid of which is one of the objects of the concluding processes.

The sugar is next removed to moulds in the *fill-house*, which is situated in the lowest story, and on a level with the heater. The conical sugar moulds are made of brown earthenware, or of sheet iron well covered with paint; the pointed ends are open; and the moulds vary in size according to the quality of the sugar, the largest moulds being used for the inferior sorts. At the time of the writer's visit to the fill-house, one set of men were engaged washing

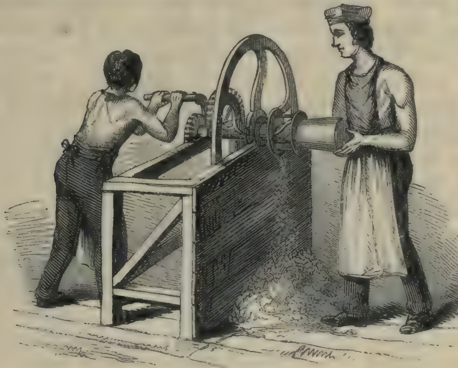
the moulds, and putting them up in piles to drain. A second set rolled these piles to another part of the floor, and placed them one by one, with their points upwards; a third set were occupied in twisting pieces of paper, with which they plugged up the holes in the moulds; a fourth set were setting up the moulds, points downwards, an operation simple in appearance, but requiring a level floor, and that kind of ready skill which can only be attained by long practice. Beginning at one corner, the moulds were arranged in ranks, four or five deep, along the whole length of the floor. A fifth set of men, eight or ten in number, were engaged in filling the moulds; each man was naked from the waist upwards, and was furnished with a copper basin, which he filled at the heater by opening a kind of sluice at the side, and then with a rapid step conveyed the syrup to the moulds, and poured it into them. Each man carried enough to fill one mould, and about half of another. A sixth set of men immediately stirred round the sugar in the moulds, to diffuse the crystals equally through the viscid mass. In this way the filling proceeded until the contents of the heater were exhausted, and as the moulds were filled, fresh rows were arranged in front of the former; until at length a considerable portion of the extensive floor was occupied. Part of this busy scene is represented in the frontispiece.

Matters remain in this condition until the next day, when the sugar has become partially solid: the moulds are then moved through the *pull-up hole* into an upper floor, which is maintained, by means of steam-pipes, at a temperature of 80°; the paper plugs are removed, and a wire is passed through the hole to ensure an open channel; the moulds are then set in earthen jars, or are hung in a frame work over a gutter terminating in a sunken cistern. The syrup which flows off is of a greenish colour, and being collected and reboiled with raw sugar, it produces an inferior quality of lump sugar; this again furnishes

a syrup, which supplies a yet lower description of sugar, and when all the crystalline particles have been removed, the residue is sold as *treacle.*

In the course of two or three days the drainage is complete: but there still remains a portion of syrup and uncrystalline matter entangled with the solid sugar. To get rid of this, a process of washing is adopted, which, under the old method, was performed by *claying,* as already described; but now by a process, one of Mr. Howard's valuable improvements, which accomplishes the work in one-fourth of the time formerly required. Some finely clarified syrup is made by dissolving in warm water loaf sugar, consisting of the turnings obtained by a subsequent process, and such loaves as do not satisfy the critical eye of the refiner, either by their shape or crystalline texture. The syrup thus obtained is poured, to the depth of about an inch, upon the broad part of each cone, the surface of which has been previously broken up and made level by an iron tool called a *bottoming trowel.* As this syrup is concentrated, it can dissolve none of the sugar already crystallized, but readily unites with molasses and colouring matter which do not crystallize, and gradually drains away with them. The loaf improves in whiteness, from the base to the point, every time this operation is performed. A few moulds are emptied from time to time to examine the success of the blanching; and when the loaves have acquired as much *colour* (as the whiteness is called by the refiners) as is judged necessary, and are sufficiently dry, they are *netted,* that is, made *net,* or *neat,* in appearance. The moulds are taken, one by one, and placed across a trough, and the base scraped with the bottoming-trowel, so as to produce an even surface: this operation is called *brushing-off.* A few blows being applied to the mould, the sugar is loosened, and turned out upon its base. If the sugar is of the best quality, it is of a perfectly pure white, from

the base to within five or six inches of the point, and here a portion of moisture and colouring matter still remains, which is removed by the process



TURNING OFF.

cess of *turning off*. This is effected by cutting blades, arranged in a conical form, connected with wheel-work, to which motion is given by one man, while another gradually introduces the loaf within the space formed by the knives, whereby the coloured damp portion is removed, and the loaf improved in shape. Loaves of coarser sugar are not turned off, but the damp ends are cut off, leaving them in the form of a truncated cone. The loaves are then removed to an oven, which occupies nearly the whole height of the building, upon a base of not more than ten feet square. This oven is provided with open frames, from the base to the top, upon which the loaves are arranged, and a constant temperature of about 140° is maintained, by a numerous assemblage of steam pipes. When sufficiently dry, the loaves are taken out, tied up in paper, and are then fit for the grocer's shop.

The routine of operations at the refinery takes about a fortnight, during which various qualities of

sugar are produced; *first*, white *loaves* of the finest quality, obtained directly from the raw or muscovado sugar; *secondly*, a second quality called *lumps*, composed of the *second runnings*, which are the syrup used in washing the loaves after the *green* syrup is separated; *thirdly*, an inferior quality, composed of the green syrup, mixed with raw sugar, producing what are called *bastards*. These are crushed into powder, and sold as a superior kind of *moist* sugar; *fourthly*, several inferior kinds of sugar are produced from the refuse matter, consisting of the impurities collected in the bag-filters, the scrapings of the various floors, and the *waste*, which in the several departments of an extensive refinery is necessarily great. All these sources of sugar are carefully collected; the crystalline particles separated from the treacle, and this again from dirt, and other impurities, which are finally sold as manure. Every third week the routine is again com-

SUGAR OVEN.

menced, and carried on during another fortnight of twelve days; for it is satisfactory to learn that, in this manufacture, Sunday is a day of rest.

As some of the different qualities of sugar are

being forwarded a stage at the same point of time, the stranger is somewhat embarrassed to notice such various results produced, as it were, by the same means. But on clearly understanding the economy of the refinery, he will be able to trace the pure white loaves, from the raw sugar in the hogshead to its final completion, passing over, as accidental or subsidiary, the various arrangements whereby inferior loaves are produced, or in other words, whereby waste is prevented. In such a case the refinery presents points of the highest interest. It is curious to witness the application of so much science, ingenuity, skill, and capital, to the production of an article which, after all, is one of mere luxury, and, according to Dr. Prout, is inferior in nutritive properties to the raw sugar which furnishes it, a circumstance which may afford some satisfaction to those persons whose means will not allow them to use white sugar. The working floors of the refinery, containing many thousand moulds filled with sugar, are peculiarly striking. The utmost care is taken to guard the sugar from speck or stain, but the floors themselves are not so privileged: during the processes of *filling* and *washing*, small quantities of syrup are being constantly spilt, and this is soon trampled into a thick viscid mud, which adheres to the feet, and in some places actually impedes motion. Heat is every where present, and often to an oppressive degree, but its source is seldom seen; the system of heating by steam has enabled the refiner to regulate the supply of heat as he may desire, and has also rendered perfectly safe a process which was formerly very hazardous. The effect of the various modern improvements has greatly reduced the price of refined sugar; at one time its price was 40 per cent. greater than raw sugar, but now the difference in price is not more than 20 per cent.

SUGAR-CANDY.

One of the oldest methods of refining sugar was to allow the syrup to form large crystals, a plan which is now adopted in the manufacture of sugar-candy. The modern process is as follows:—

The syrup, being properly clarified, is poured into old moulds, within which small twigs are placed, or strings of packthread stretched. As the syrup cools, crystals collect round the twigs or strings, the size of the crystals increasing gradually from day to day. In about nine or ten days the moulds are placed in pots in a hot room; the syrup is allowed to drain off, and the candy is dried. Coloured or perfumed sugar-candy is made by mixing cochineal, indigo, or some colouring matter, or scent, with the syrup.

Candy is the only kind of refined sugar made in China and India. The Chinese are celebrated for it, and export it largely.

Candy is less easily dissolved than loaf sugar, and this does not melt so easily as raw sugar: hence it is said that raw sugar "sweetens better" than the other two: but the greater or less intensity of sweetness seems to depend upon the quickness with which it dissolves; for there cannot be a doubt that when once dissolved, the purer the sugar, the more perfectly is the saccharine principle developed.

STATISTICS OF SUGAR.

The consumption of sugar in different years is liable to great fluctuation, arising from variation in price, and the means of the people to purchase; but it has been calculated that the annual consumption averages about 20 lbs. per head for Great Britain; about 5 lbs. per head for France; 4 lbs. for Germany; and about $2\frac{1}{2}$ lbs. for other parts of Europe.

In the year 1839, the quantity of cane sugar produced in different parts of the world was estimated as follows :—

		Cwts.
The British Sugar Colonies exported	. . . .	3,571,378
British India	"	519,126
Danish West Indies	"	450,000
Dutch Ditto	"	260,060
French Sugar Colonies	"	2,160,000
United States of America	"	900,000
Brazil	"	2,400,000
Spanish West Indies	"	4,481,342
Java	"	892,475
Exported for internal consumption, exclusive of China, India, Siam, Java, and the United States	. . .	2,446,337
		18,080,718

Between one-fourth and one-fifth of this quantity is consumed in the United Kingdom. The quantities imported during three years, are as follows:—

	1839. Cwts.	1840. Cwts.	1841. Cwts.
West India, of British Possessions	2,823,931	2,202,833	2,145,500
East " " " . .	518,925	482,824	1,239,738
East " of Foreign " . .	722,777	—	803,668
Mauritius	612,586	545,009	716,112
Foreign	722,777	805,179	—

The duty on sugar from British possessions was during many years 24*s*. per cwt.; foreign sugars paid a duty of 63*s*. per cwt. The net revenue from this source, for 1839, was 4,586,936*l*.; for 1840, 4,449,033*l*.; and for 1841, 5,114,390*l*. By a recent act of the legislature the duties payable on the importation of sugar, subject to minor exceptions, depending on reciprocity treaties, and other circumstances, are as follow :—

	Per Cwt.		
Sugar grown in British West Indies or East Indies—			
Double Refined	£1	1	0
Refined	0	18	8
Clayed	0	16	4
Brown, or Muscovado	0	14	0
Molasses	0	5	3
Sugar grown in other British Colonies—			
Clayed	1	1	9
Brown	0	18	8

Sugar grown by *free* labour in Foreign Countries—

Clayed	£1	8	0
Brown	1	3	4

Sugar grown by *slave* labour in Foreign Countries—

Refined	8	8	0
Brown	3	3	0
Molasses	1	3	9

Before these alterations, refined sugar was not allowed to be made in any of our colonies, but was reserved for the advantage of this country: considerable quantities were, therefore, annually exported. In the year ending 25th June, 1840, the chief export of British refined sugar was as follows:—

	Cwts.
To Italy	40,000
" British North America	37,000
" Turkey	30,000
" Russia	20,000
" Australian Settlements	11,000
" British West Indies	10,500

Although foreign sugar paid nearly three times the duty charged on our colonial sugar, yet the refiner was permitted to refine it *in bond* for exportation, a drawback being allowed in the proportion of 34 cwt. of raw to 20 cwt. of refined.

The men engaged in the sugar refinery appear to enjoy average good health. In some of the processes, they are exposed to a warm damp atmosphere, and in others to a hot dry air; but they are not long enough at them to suffer injuriously, the nature of the work leading them to conduct other processes which are rather healthy than otherwise. The preparation of the bone black is peculiarly disagreeable and dirty,—the air of the room in which it is performed being very hot, and loaded with particles of dust; but this is usually a separate trade.


COTTON.
THE
SPINNING-WHEEL.

THE

MANUFACTURE OF COTTON YARN.

PART I.

HISTORY furnishes no example to compare with the rapid growth and prosperity of the cotton-trade in this country. In the early part of the eighteenth century, the total quantity of cotton-wool annually imported into Great Britain did not much exceed one million pounds in weight: the quantity imported in the year 1844, amounted to 646,111,304 pounds, of which 554,196,602 pounds were retained for home consumption. When George the Third came to the throne, in 1760, the entire value of all the cotton goods manufactured in Great Britain, amounted to the annual sum of about two hundred thousand pounds: the declared value of our *exports* only, in cotton goods, amounted in the year 1844, to 25,805,348*l.*; while the quantity retained for home consumption is supposed to exceed in value ten millions of pounds sterling.

This astonishing progress has been made in spite of difficulties which, at first view, would appear almost insurmountable. Before the year 1790, North America, (whence our present supply is chiefly obtained,) did not furnish us with a single pound of cotton; and the inhabitants of Hindustan and China had obtained such celebrity for the lightness and delicacy of their cotton goods, as apparently to bid

defiance to competition. Such, however, has been the effect of the improvements and inventions, chiefly of a few illiterate mechanics, aided by the stupendous steam-engine of Watt, that the Hindoo now entrusts the raw material to the British merchant, who, after carrying it five thousand miles to be manufactured, returns it in the form of goods, which successfully rival those of Hindustan and China. The Hindoo, incessantly urging his rude spinning-wheel, produces scarcely a pound of thread in a long working day: in a modern cotton-mill, each spindle will produce upwards of a mile and a quarter of thread in twelve hours; and, as in many mills not fewer than fifty thousand spindles are mounted, it will be found that a sufficient length of thread may be spun every day, in one of these mills, to go two and a half times round the globe.

HISTORY OF THE COTTON PLANT.

Of the four raw materials which supply clothing, *flax* is said to have belonged originally to Egypt; the sheep, which furnishes *wool*, to the mountain ranges of Asia; the *silk*-worm to China; and the *cotton* plant to India and America.

Although cotton was not generally known among the nations of the earth until a much later period than the other three substances, it is now raised in such abundance as to be the cheapest of all clothing. From its great resemblance to sheep's wool, it was called by the ancients "the wool of trees;" and, although it differs greatly in its properties from the animal fleece, the term is still retained. The Germans call it *baumwolle*, or tree-wool, and the French *coton en laine*, which answers to the English term *cotton wool*.

Cotton wool is contained in the seed-vessels of a plant belonging to the natural order Malvaceæ, or

HERBACEOUS COTTON (*Gossypium herbaceum*).

mallows, and of the genus *Gossypium.* There are many varieties of the plant, which have been divided into *herbaceous* cotton, *shrub* cotton, and *tree* cotton, according to the mode of growth. Of these, the most useful is the herbaceous, which is extensively cultivated in the southern parts of the United States of America, in India, China, and other warm climates. The cultivators of Georgia and the neighbouring states grow three varieties of herbaceous cotton : *first, nankin* cotton, bearing the yellow wool of which the well-known cloths called *nankeens* are made; but of this the quantity is very limited : *secondly,* that which is known in the country as *green-seed* cotton, of which the wool is white. These two grow in the midland and upland districts; and hence the white variety is known to the Liverpool dealers as *Upland* cotton. It is also called *bowed Georgia cotton,* from a method of cleaning it, which will be described presently, and also *short-staple* cotton, which refers to the length of its fibre. The *third* and most esteemed variety is the *sea-island* cotton, which is of *long-staple;* its fibre being much longer than that of any other description :

it is strong and even, of silky texture, and has a yellowish tinge, which, in all cotton, when not produced by accidental wetting, or by inclement seasons, is regarded as a mark of superior fineness. The seed of the sea-island cotton is black, while most of the other American cotton is produced from green seed. It is an annual herbaceous plant, and being found to thrive in the low, sandy islands which lie along the coast from Charleston to Savannah, the cotton hence derives its name.

Herbaceous cotton attains a height of from eighteen to twenty-four inches; its leaves, which are of a bright dark-green colour, are marked with brownish veins, and are divided each into five lobes. The blossom expands into a pale yellow flower, which, falling off, a pointed triangular pod appears, containing three cells: this gradually increases to the size of a large filbert, and becomes brown as the woolly fruit ripens; the expansion of the wool then causes the pod to burst, when there appears a ball of snowy-white, or of yellowish down, consisting of three locks, one for each cell, enclosing and firmly adhering to the seeds, which are larger than grapes, but of similar form. The appearance of a cotton field, while the pods are progressively opening, is described as being highly interesting; "the fine dark-green of the leaf contrasting beautifully with the brilliant white of the cotton suspended from the pods and floating to and fro at the bidding of the wind."

Shrub cotton grows in most countries where the annual herbaceous cotton is found. In the West Indies, its duration is about two or three years; in India, Egypt, and some other places, it lasts from six to ten years; in the hottest countries it is perennial, and furnishes two crops a-year; in cooler climes it is annual. In appearance it is much like a currant bush.

Tree cotton grows in India, China, Egypt, and in the interior and on the western coast of Africa, and

in some parts of America. It attains a height of from twelve to twenty feet.

TREE COTTON (*Gossypium arboreum*).

The cotton plant requires a dry, sandy soil, and thrives where the land is too poor to produce any other valuable crop. Wet seasons are usually fatal, but the vicinity of the sea is favourable to the production of the best cotton. The salt clay mud is an excellent manure, and the saline breezes promote the growth of the plant. The places in which the celebrated sea-island cotton is grown have many advantages; but, being much exposed to the inclemencies of the weather, the produce varies greatly in quality.

Great care is bestowed in America upon the cultivation of the cotton plant. The seed is sown by hand in March and the two following months,

according to the season. It is planted in rows five feet asunder, and in holes eighteen inches apart, in each of which several seeds are placed. The land is carefully weeded at short intervals; and as the plants come up, the weakest are drawn out, only two or three being left in each hole. When the plants are a few months old, they are again weeded and thinned, and the stems and branches *topped* off, to the extent of an inch or more from each shoot; the effect of which is to retard the growth of the plant in height, and to promote the development of the side branches. Some of the lower leaves are occasionally taken off. Good cotton cannot be produced without constant care and attention, up to the period of flowering. In India, the mode of cultivation is very slovenly, and little or no care is bestowed on the plant, the consequence of which is, that the produce is greatly inferior to that of the United States.

The operation of gathering requires much care. The gatherers, consisting chiefly of women and young people, go into the field with baskets or bags suspended from their shoulders, for the reception of such portions of the wool as they find sufficiently ripe. The usual method is to take away the seeds and cotton, leaving the empty husks; but in the East the whole pod is gathered, a method which is somewhat more expeditious, but has the serious disadvantage of injuring the cotton; for the husk breaks into small pieces, mixes with the cotton, and cannot easily be separated from it.

The gathering is always performed in fine weather, after the morning dew has disappeared, as any moisture would make the cotton mouldy, and cause the oil of the seeds to spread over the wool. The cotton is more completely dried by exposure to the heat of the sun or of stoves, on a platform of tiles or wood, during several days, whereby the seeds are afterwards more easily separated.

As the cotton does not all ripen at the same time,

the gatherers have to go over the same plantation many times. If the cotton is not gathered soon after the pods have burst, the heat of the sun injures its colour, or it may be blown away by the wind or spoiled by the rain or dew.

But, between the sowing of the seed and the gathering of the crop, many accidents may arise to defeat the hopes and precautions of the cultivator. The cotton plant is subject to many diseases, the most formidable of which, called the *blast*, is occasioned by excessive moisture, whereby the roots rot and the plant perishes. This often happens in land which has not been properly drained. In wet seasons the plant is sometimes subject to a sort of over-growth, and the fruit is destroyed from excess of vegetation. In times of excessive drought, on the other hand, the plant is affected with a kind of *gangrene*, and appears as if scorched with fire; many blossoms fall off unproductive, and the pods which are formed are black; after which the foot-stalks wither and rot, and the pods fall to the earth. In this condition nothing but careful pruning and most favourable weather will save the plant; but these remedies are often defeated by an insect called the *cotton bug*, which infests the pod in immense numbers, and contributes greatly to the destruction of the crop. But the most rapacious insect-destroyer of this plant is the *chenille*, or *cotton caterpillar*. This insect, which is about an inch or an inch and a half long, sometimes appears singly, but at other times in such swarms that whole plantations are completely devoured in one night, not leaving a single leaf, flower, pod, or green sprout. It is singular, that, although this insect gives out no smell, and the plants are also inodorous, yet, while the chenille is feeding on its leaves, a strong fragrant smell is perceptible at more than a hundred yards distance. As soon as one field is destroyed, the insect army marches away to another, often at some distance, passing several fields without attacking them. Unless their progress

is stopped, they commit fearful havoc, but happily there are several natural enemies of the chenille. Turkies destroy prodigious numbers of the larvæ; the house-wren is also fond of them; and there is one bird—the black and yellow manakyn—that seeks them out with so much industry that it has obtained the name of the *chenille-bird.* Some cultivators destroy these insects by the fumes of sulphur; one person holding a dish of burning sulphur under the trees, while another covers them with a canvas hood, to confine the vapour. Another description of caterpillar, which remains buried in the ground, occasionally does much mischief, by gnawing the stalk of the plant about half an inch from the surface.

But, supposing the cultivator has escaped the more serious attacks of the enemies of his crop, and has gathered in and dried a good store of cotton, he must be careful to separate the seeds from the wool before it is packed; otherwise it would become oily and mouldy. The fibres of the cotton adhere so firmly to the seed, that when the picking is done by hand, as it is in some parts of India, a man can scarcely clean more than a pound of cotton in a day. In other parts of India, as also in China, a rude hand-mill, or roller-gin, is employed. It consists of two fluted wooden rollers, placed horizontally, one above the other, on a stand a few feet from the ground, and

PRIMITIVE COTTON-GIN.

moving round nearly in contact. The upper roller is turned by a handle, and the lower is carried along with it by a perpetual screw at the axis. The cotton is put in at one side, and drawn through by the revolving rollers; but the seeds, being too large to pass through the opening, are torn off, and fall down on the opposite side from the cotton. By this method, one workman is able to separate from seed, from forty to sixty-five pounds of cotton a-day.

"BOWING" COTTON.

The cotton is then *bowed*, to clear it from dirt and knots. A large bow, made elastic by a complication of strings, is used: this being put in contact with a heap of cotton, the workman strikes the string with a heavy wooden mallet, and its vibrations open the knots of the cotton, shake from it the dust and dirt, and raise it into a downy fleece. The hand-mill and the bow have been used from time immemorial in many parts of Asia, and they were formerly used in America, whence the term *bowed Georgia cotton* still retained in commerce.

The long-stapled, or sea-island cotton, is still separated from its seeds by rollers, constructed on a large scale, and worked by horses, or steam, or water power. A mill of this kind, capable of cleaning eight or nine hundred pounds of cotton in a day, has been described by Captain Basil Hall. It consists of two wooden rollers of about an inch in diameter; these are placed horizontally, parallel, and touching each other. Over them is fixed a sort of comb, having iron teeth two inches long, and seven-eighths of an inch apart. This comb is of the same length as the rollers, and is so placed that its teeth come nearly in contact with them. When the machine is set in motion, the rollers are made to revolve with great rapidity, so that the cotton, being laid upon them, is by their motion drawn in between the two, whilst no space is left for the seeds to pass with it. To detach these from the fibres of cotton, in which they are enveloped, the same machinery which impels the rollers, gives to the toothed instrument above a quick wagging motion to and fro, by means of which the pods of cotton, as they are cast upon the rollers, are torn open, just as they are beginning to be drawn in: the seeds, now released from the coating which had encircled them, fly off, like sparks, to the right and left, while the cotton itself passes between the rollers. The sharp iron teeth of the comb, moving very rapidly, sometimes break the seeds; then the minute

pieces are instantly hurried on, and pass between the rollers with the cotton. These stray particles are afterwards separated by hand, a process which is called *moting*. In order to cleanse the cotton entirely from any remaining fragment of seed, it is subjected to another process. This consists of whisking it about in a light wheel, through which a current of air is made to pass. As it is tossed out of this winnowing machine, it is gathered up and conveyed to the packing house, where, by means of screws, it is forced into bags, each, when filled, weighing about three hundred pounds. These are then sewed up, and sent to the place of shipment, where they are again pressed, and reduced to half their original size. The short-stapled cotton is compressed by means of the hydraulic press, five or six hundred weight being packed into a bulk of twelve or thirteen cubic feet. The average gross weight of a bag of cotton from the United States, varies from 330 to 350lbs.

The above method of separating the seed from the wool, answers very well for the sea-island, or black-seeded cotton; but in the green-seeded, or short-stapled varieties, the seeds retain the wool with so much force, that a more powerful machine is required. This is the *saw-gin*, invented by Mr. Eli Whitney, a native of Massachusetts, by which three hundred weight of cotton may be cleaned in a day. In this machine "the cotton is put into a receiver, or hopper, of considerable length, compared with its width, one side of which is formed by a grating of strong parallel wires, about an eighth of an inch apart. Close to the hopper is a wooden roller, having upon its surface a series of circular saws, an inch and a half apart, which pass within the grating of the hopper to a certain depth. When the roller is turned, the teeth of the saws lay hold of the locks of cotton, and drag them through the wires, whilst the seeds are prevented, by their size, from passing through, and fall to the bottom of the receiver, where they

are carried off by a spout. The cotton is afterwards swept from the saws by a revolving cylindrical brush. When first invented, the wooden cylinder was covered with teeth of wire like cards, but the saw was found to answer the purpose better. The saw-gin injures, in some degree, the fibre of the cotton; but it affords so cheap a way of cleaning it, that all the North American cotton, except the sea-island, undergoes this operation."*

It is very probable, that but for this invention, the commoner sorts of cotton could not have been cultivated with success, as a more costly method of cleaning would have raised their price in the market to a degree sufficient to exclude them. This invention has had considerable influence in promoting the growth and exports of cotton from the United States; so that Eli Whitney, as it has been well remarked, "did for the planters of the southern states, what the genius of Arkwright and Watt did for the manufacturers of England." Before the year 1790, North America supplied us with no cotton. In 1791 a trifling quantity was exported. In 1793 the saw-gin came into operation; and after this there is nothing in the history of industry to compare with the increase of the American cotton trade, unless it be the growth of the manufacture in this country. The following is an extract from the official returns of the exports of cotton from the United States to various parts of the world:—

	lbs.		*lbs.*
1791	189,316	1805	40,383,491
1792	138,328	1810	93,874,201
1794	1,601,760	1820	127,860,152
1795	5,276,300	1825	176,439,907
1798	9,360,005	1830	298,459,102
1800	17,789,803	1841	530,204,100

In the year 1844 the quantity of cotton wool sent from the United States to this country alone, amounted to 517,218,622lbs.

* BAINES, *History of the Cotton Manufacture.*

HISTORICAL NOTICES OF THE COTTON MANUFACTURE.

Writers of antiquity abound in allusions to clothing made of wool and flax; there are, however, but few notices among Greek and Latin writers, and not one among Hebrew writers, referring to cotton. In the old world the growth and manufacture of cotton were confined to those populous regions lying beyond the Indus, which were long unknown to the nations bordering on the Mediterranean; and even in modern times, in the middle ages, continual mention is made of stuffs of woollen, linen, silk, and gold, but cotton remains unnoticed.

Wool was probably one of the first materials used by mankind for cloth. It is mentioned in the Scriptures in connexion with linen, (Deut. xxii. 11; Prov. xxxi. 13); and the manufacture of both these fabrics existed in Greece in the days of Homer.

The arts of spinning and weaving rank next in importance among mankind to agriculture, and must have been invented at a very early period in man's history. They existed in considerable perfection in Egypt, at the time when the Israelites were in bondage in that land. Linen was the national manufacture among the ancient Egyptians. That they were not acquainted with cotton seems evident, from the fact, that among the numerous specimens of mummy-cloth which have been imported into Europe, no cotton has been found; and there are no paintings of the cotton shrub upon the tombs of Thebes, where accurate representations of flax occur in its different states of growth and manufacture. In India, cotton was probably manufactured at as early a period as linen in Egypt, for Herodotus (who wrote about 445 B.C.) speaks of the manufacture among the Indians as if it were in a very advanced state. He

says :—"They possess a kind of plant, which instead of fruit produces *wool*, of a finer and better quality than that of sheep; of this the Indians make their clothes." Nearchus, the admiral to whom Alexander entrusted the survey of the Indus, (B.C. 327) states, that "the Indians wore linen garments, the substance whereof they were made growing upon trees; and this is indeed flax, or rather something much whiter and finer than flax. They wear shirts of the same, which reach down to the middle of their legs; and veils, which cover their head and a great part of their shoulders." Strabo also, on the authority of Nearchus, mentions the Indians as being celebrated for flowered cottons or chintzes, and for their various and beautiful dyes. This geographer states, that in his own day (he died A.D. 25) cotton grew, and cotton cloths were manufactured in Susiana, at the head of the Persian gulf. Fifty years later Pliny describes the cotton plant and the stuffs made from it. He says, "In upper Egypt, towards Arabia, there grows a shrub, which some call *gossypium*, and others *xylon*, from which the stuffs are made, which we call *xylina*. It is small, and bears a fruit resembling the filbert, within which is a downy wool, which is spun into thread. There is nothing to be preferred to these stuffs for whiteness or softness: beautiful garments are made from them for the priests of Egypt." The same author, in his description of the island of Tylos, in the Persian gulf, enumerates, among its remarkable productions, wool-bearing trees, with leaves exactly like those of the vine, but smaller, bearing a fruit like a gourd, and of the size of a quince, which, bursting when it is ripe, displays a ball of downy wool, from which are made costly garments resembling linen." Arrian, an Egyptian Greek, who lived in the first or second century, notices the exports from India of calicoes, muslins, and other cottons, both plain, and ornamented with flowers, made in the interior provinces; that Masalia,

the modern Masulipatam, was then, as it has been ever since, famous for the manufacture of cotton piece-goods; and that the muslins of Bengal were then, as at the present day, superior to all others, and received from the Greeks the name of *Gangitiki*, indicating that they were made on the borders of the Ganges.

Cottons and muslins gradually came into use in Arabia and the neighbouring countries, and the manufacture was diffused by the commercial activity and enterprise of the early followers of Mohammed. The fabrics called *muslins* received their name from *Mosul* in Mesopotamia; as, in the same way, at a later period, *calico* was named after *Calicut;* and the yellowish brown cotton fabrics, called *nankeens,* after the city *Nankin.*

Marco Polo, who visited most of the principal cities of Asia at the latter part of the thirteenth century, notices a manufacture of very fine cotton cloth at Arzingan, in Armenia Major: he states that cotton was abundantly grown and manufactured in Persia and all the provinces bordering the Indus, and that in all parts of India this was the staple manufacture. He also notices, that in the province of Fokien, in China, cottons were woven of coloured threads, which were carried for sale to every part of the province of Mangi; but that silk was the ordinary dress of the people, from the prince to the peasant. The cotton plant first began to be cultivated for common use after the conquest of the empire by the Tartars; a strong resistance was made to its cultivation by the fabricators of wool and silk, but the opposition was soon put down, because, among all the materials of clothing, cotton was found to be best suited to the torrid zone, and the cheapest material of which cloth could be made; therefore, about the year 1368, the cultivation began to prevail throughout the empire. The Chinese cottons, especially the nankeens, have acquired much celebrity. At the present day cotton is not grown in sufficient quantity for the consump-

tion of that empire, so that it is largely imported from India.

Cotton cloth, of African manufacture, was brought to London from Benin, on the coast of Guinea, in 1590. The cotton tree grows plentifully on the borders of the Senegal, the Gambia, and the Niger rivers; at Timbuctoo, Sierra Leone, in the Cape de Verd Islands, on the coast of Guinea, in Abyssinia, and throughout the interior. The peculiar fitness of the soil and climate of Egypt prompted the present ruler of that country, a few years ago, to introduce the cotton plant, and in two years he exported no less than 5,623 bales to England. As this cotton was raised from the Georgian Sea-Island seeds, it is called *Sea-Island Egyptian cotton.*

The cotton manufacture was found in a very advanced state in America on the discovery of that continent by the Spaniards. Clavigero states, that "of cotton the Mexicans made large webs, and as delicate and fine as those of Holland, which were, with much reason, highly esteemed in Europe. They wove their cloths of different figures and colours, representing different animals and flowers. Of feathers, interwoven with cotton, they made mantles and bed-curtains, carpets, gowns, and other things, not less soft than beautiful. With cotton also they interwove the finest hair of the belly of rabbits and hares, after having made and spun it into thread; of this they made most beautiful cloths, and in particular winter waistcoats for their lords." Among the presents sent by Cortez to Charles the Fifth, were "cotton mantles, some all white, others mixed with white and black, or red, green, yellow, and blue; waistcoats, handkerchiefs, counterpanes, tapestries, and carpets of cotton." Columbus found the cotton plant growing wild in the West India Islands, and on the continent of South America, where the inhabitants wore cotton dresses, and made their fishing nets of the same material.

To Spain belongs the honour of having introduced the cotton manufacture into Europe. The plant was cultivated and manufactured into clothing in Spain as early as the tenth century, about which time it was probably introduced by the Moors. It flourished on the fertile plains of Valencia, where it still grows wild. During some centuries Barcelona was celebrated for the manufacture of cotton sail-cloth and fustians, the latter being a strong fabric used to line garments, and which derives its name from the Spanish word *fuste*, signifying "substance." The Spanish Arabs made paper from cotton before that most useful article was known in Europe. When the Moors were expelled from Spain, the useful arts disappeared with them, and only by slow and laborious efforts were they introduced into other parts of Europe. The cotton manufacture is said to have been introduced at Venice at the beginning of the fourteenth century. Strong cottons, such as fustians and dimities, were made at Venice and Milan; and it is probable that even those were woven with a linen warp and a cotton weft, as was afterwards the custom in England, from the difficulty, at that early period, of making the long, or warp threads, of sufficient strength in cotton to bear stretching in the loom. It is supposed that about this time cotton yarn was imported from Syria and Asia Minor, whence, in later times, the Italians and French obtained that article.

It must not be supposed that the cotton manufacture, as it now exists in England, was borrowed from any other nation. The present manufacture is due entirely to the genius and enterprise of Englishmen; and during little more than half a century it has sprung into existence, and become a sort of centre to the commercial world. At the early period to which our history refers, the only fabric manufactured in this country was a coarse and heavy article, probably half cotton and half linen, of too

little importance to attract much notice; but calico, muslin, and the more delicate cotton goods, were never made in Europe, except possibly by the Moors in the south of Spain, until the invention of the spinning machinery in England.

At an early period, the fabrics made at Manchester, and some other towns in Lancashire, were for some reason called *cottons*, though they were actually *woollen* or *linen* goods. It has been suggested, that the word *cottons*, at that day, was only a corruption of *coatings*. The first notice on this subject is by Leland, who visited Lancashire in the reign of Henry the Eighth. He says: "Bolton-upon-Moore market standeth most by *cottons:* divers villages, in the moores about Bolton, do make *cottons*." This apparent proof of the early existence of the cotton manufacture is, however, disproved by an act of Edward the Sixth (1552), entitled, "For the true making of *woollen* cloth;" in which it is ordered, that all the cottons called Manchester, Lancashire, and Cheshire cottons shall be of certain specified dimensions and weights, which could by no means apply to cottons, but only to coarse woollens. Camden, speaking of Manchester in 1590, says: "This town excels the towns immediately around it, in handsomeness, populousness, woollen manufactures, market-place, church, and college, but did much more excel them in the last age, as well by the glory of its woollen cloths, which they call Manchester *cottons*, as by the privilege of sanctuary, which the authority of parliament, under Henry the Eighth, transferred to Chester."

It seems impossible to fix the date of the introduction of the cotton manufacture in England. The earliest actual record on the subject is a work published in the year 1641, called "The Treasure of Traffic," by Lewis Roberts. Speaking of the town of Manchester, he says, "They buy *cotton wool* in London, that comes first from Cyprus and Smyrna,

and at home worke the same and perfect it into *fustians, vermillions, dimities*, and other stuffes, and then return it to London, where the same is sold, and not seldom sent into forrain parts, who have means, at far easier termes, to provide themselves of the said first materials."

It appears, therefore, that, in the year 1641, the cotton manufacture had become fairly established in Manchester, from which town not only the home trade, but the distant markets of the Levant, were supplied with several descriptions of cotton goods. The linen manufacture still continued to flourish in Manchester, and indeed linen yarn was used as the warp for fustians, and for most cotton goods in this country, down to the year 1773.

Dr. Fuller, who wrote in 1662, says that the inhabitants of Manchester, "buying the *cotton wool* or *yarne* coming from beyond the sea, make it here into fustians, to the good employment of the poor, and great improvement of the rich therein, serving mean people for their outsides, and their betters for the lining of their garments. Bolton is the staple place for this commodity, being brought thither from all parts of the country. As for Manchester, the *cottons* thereof carry away the credit in our nation, and so they did a hundred and fifty years agoe. For, when learned Leland, on the cost of King Henry the Eighth, with his guide, travailed Lanchashire, he called Manchester the fairest and quickest town in this country; and sure I am it hath lost neither spruceness nor spirits since that time. Other commodities made in Manchester are so small in themselves, and various in their kinds, they will fill the shop of a haberdasher of small wares. Being, therefore, too many for me to reckon up or remember, it will be the safest way to wrap them all together in some *Manchester ticken*, and to fasten them with the *pinns* (to prevent their falling out and scattering), or

tye them with the *tape*; and also, because sure bind, sure find, to bind them about the *points* and *laces* all made in the same place."

Mr. Baines is inclined to think, that the art was brought from Flanders, by the Protestant artisans and workmen who fled from Antwerp on the capture and ruin of that great trading city, by the Duke of Parma, in 1585, and also from other cities of the Spanish Netherlands. "Great numbers of these victims of a sanguinary persecution took refuge in England, and some of them settled in Manchester; and there is the stronger reason to suppose that the manufacture of cotton would then be commenced here, as there were restrictions and burdens on foreigners setting up business as masters in England, in the trades then carried on in this country, whilst foreigners commencing a *new* art would be exempt from those restrictions. The warden and fellows of Manchester college had the wisdom to encourage the settlement of the foreign clothiers in that town, by allowing them to cut firing from their extensive woods, as well as to take the timber necessary for the construction of their looms, on paying the small sum of fourpence yearly. At that period of our history, when capital was small, and the movements of trade comparatively sluggish, a new manufacture would be likely to extend itself slowly, and to be long before it attracted the notice of authors. That a manufacture might in those days gradually take root, and acquire strength, without even for half a century being commemorated in any book that should be extant after the lapse of two centuries more, will be easily credited by those who have searched for the records of our modern improvements in the same manufacture. If the greatest mechanical inventions, and the most stupendous commercial phenomena, have passed almost unnoticed in a day when authors were so numerous, the mere infancy of the cotton

manufacture may well have been without record in an age when the press was far less active."

EARLY METHODS OF SPINNING.

THE DISTAFF AND SPINDLE.—THE SPINNING-WHEEL.

AMONG the ancient Egyptians, who were so celebrated for their fine linen, spinning was a domestic occupation common to all ranks of society; and, in

MODERN EGYPTIAN SPINNING.

our own country, up to a very recent period, the spinning-wheel was an ordinary piece of domestic furniture. The term "spinster," applied to unmarried females, shows how universal was the employment of preparing thread or yarn for the weaver. Before the invention of the spinning-wheel, the distaff and rock, or spindle, were the simple instruments employed by the spinster. The distaff was a stick or reed, about a yard in length, with a fork or expansion near the top, round which the cotton was wound, being previously prepared by carding or combing. The distaff was usually held under the left arm, and

the fibres were drawn out from the projecting ball, being at the same time spirally twisted by the forefinger and thumb of the right hand. The thread so

SPINNING WITH DISTAFF AND SPINDLE.

produced was spun by the turning round of the spindle, and was then wound upon it until the quantity was as great as it would carry. A fresh spindle was then mounted, and those already loaded with thread were stored in a basket until a sufficient quantity were collected for the weaver.

The spindle was made of a reed, or of some light wood, and was generally from eight to twelve inches in length. At the top was a slit or clasp, for attaching the thread, so that the weight of the spindle might keep it stretched. The lower end was inserted in a whorl or wheel, made of some heavy material, which served to keep it steady, and to promote its rotation. The spinner every now and then gave the spindle a fresh turn, so as to increase the twist of the thread.

When the spindle touched the ground, "a length" was said to be spun, and the thread was taken out of the slit, and wound upon the spindle: the upper part was then inserted in the slit, and a new length commenced. The Roman poet Catullus briefly mentions these particulars:—

"The loaded distaff, in the left hand placed,
With spongy coils of snow-white wool was graced;
From these the right hand lengthening fibres drew,
Which into thread 'neath nimble fingers grew.
At intervals a gentle touch was given,
By which the twirling whorl was onward driven.
Then, when the sinking spindle reach'd the ground,
The recent thread around its spire was wound,
Until the clasp within its nipping cleft
Held fast the newly-finish'd length of weft."

In ancient times the spindle and distaff were frequently made of some precious material, beautifully ornamented. Thus Homer has mentioned the present of a golden distaff being made to Helen; and Theocritus has celebrated the distaff in his twenty-eighth Idyll, on the occasion of a visit to a friend to whose wife he presented an ivory distaff. The poem begins thus:—

"O DISTAFF, friend to warp and woof,
Minerva's gift in man's behoof,
Whom careful housewives still retain,
And gather to their household's gain,
With me repair," &c.

The Hindoos form their distaff of the leading shoot of some young tree, carefully peeled; and for the spindle they select the beautiful shrub *Euonymus*, which has hence obtained the popular name of "the spindle-tree." With these simple implements, and by means of the exquisite touch which the Hindoos possess, are spun those delicate cotton threads from which the celebrated Indian muslins are made.

The use of the spindle and distaff was superseded in England by the spinning-wheel, in or soon after the reign of Henry the Eighth. It was probably introduced from Hindustan, where it had been in use

HINDOO SPINNING-WHEEL.

for ages; but domestic legends say, that it was invented by the fairies, or some supernatural power; and, no doubt, at the time of its introduction, it was regarded as a great discovery, in which all classes of society were interested. Two kinds of household wheels have been described as long in use among spinsters; the first is commonly called, in this country, "the big wheel," from the size of its rim, or "the wool wheel," from its being employed in the spinning of sheep's wool. The Saxony, or Leipsic wheel, so called from its German origin, was used for spinning flax, and was an improvement on the old Jersey wheel, as it enabled the spinner to mount two spindles on the same wheel, so as to form a thread with each hand. The worsted wheel was also employed to spin cotton, for which it was equally well adapted; and this it did by two distinct processes. The cotton

having been picked and cleaned, was *carded* or brushed with coarse wire brushes, called *hand cards:* the cotton being spread upon one of these, was combed with the other until the fibres were all disposed in one direction: it was then taken off in soft fleecy rolls, called *cardings*, each about twelve inches long, and three quarters of an inch thick. These *cardings* were next formed into a coarse thread or *roving;* for which purpose one end of the carding was twisted round the spindle, and the spinster with the right hand turned the wheel which, by means of a band or cord, gave motion to the spindle; at the same time she drew out the carding to a certain length with the left hand. The motion thus given to the carding twisted it spirally, and extended it in length. It was then wound upon the spindle, another carding was attached to it, drawn out and twisted as before, and thus was formed a continuous coarse thread or roving. By a second and similar operation the roving was stretched and twisted into a fine strong thread, fit to be used as weft. This double process was necessary, because the cardings could not be at once drawn into a level and even thread fine enough for the loom. The preparation of the rovings was called *coarse spinning*, and that of the thread *fine spinning*. The roving, which was about the thickness of a quill, being fastened to the spindle, was held firmly between the left fore-finger and thumb, at the distance of about six inches from the spindle; the wheel was then turned with the right hand, and at the same time the left hand was drawn away about half a yard, by which means the roving was drawn out into weft; the necessary twist was then given by a few turns of the wheel; and lastly, the thread was wound upon the spindle into a conical shape, called *a pirn* or *cop*.

It has been already mentioned, that the more firm and even thread of flax was used for the warp. This was largely exported from Ireland, Scotland, and

Germany. Cotton yarns were mostly spun in the cottages of the peasantry, and gave abundant occupation to the female members of every poor family. The old dame, or the mother, at her spinning-wheel, forms a domestic picture which cannot be remembered without a feeling of regret that it has passed away for ever. It was then the custom for travelling chapmen, with their pack-horses, to go from door to door to purchase the cotton yarn which had been prepared; but these sources of supply gradually became insufficient to meet the demands of the weaver, who frequently had "to walk three or four miles in a morning, and call on five or six spinners, before he could collect weft to serve him for the remainder of the day; and when he wished to weave a piece in a shorter time than usual, a new ribbon, or a gown, was necessary to quicken the exertions of the spinners."* The prices paid to the spinner were often so high as to take away all or most of the profits of weaving. According to Dr. Taylor,† this was the commencement of the system of infant labour; for spinning being found so profitable, every child in the cottage was forced to help in the process. When the father was a weaver and the mother a spinner, the tasks imposed on the children were often cruelly severe. Indeed, with the one-thread wheel, it was scarcely possible for one person, with the greatest industry, to produce a pound of thread in a day. The goods thus manufactured were strong and coarse compared with those now produced. The thread was very unequal, its evenness depending greatly on the delicacy of touch of the spinster, and it varied with every little difference in the drawing out of the thread, and the turns of the spindle in portions of the same length.

* GUEST, *History of the Cotton Manufacture.*
† *Hand Book of Cotton, &c. Manufactures.*

THE SPINNING JENNY.—HARGREAVES.

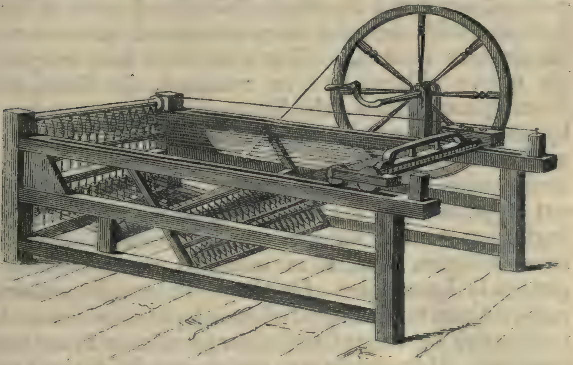
THE method of spinning with the one-thread wheel long continued to impede the progress of the manufacture, when, about the year 1764, was made the first mechanical invention profitably employed by manufacturers in England in spinning cotton yarn. This was the *Spinning Jenny*, invented by James Hargreaves,* at Stand-hill, near Blackburn, in Lancashire, near the print-ground, the first and infant establishment of the late Sir Robert Peel. Hargreaves was a plain, industrious, but illiterate man, a weaver by trade, and who, in common with others of his class, felt great difficulty in supplying his loom with yarn. The principle of his invention is precisely that

* Mr. Guest, in his History of the Cotton Manufacture, claims the invention of the spinning jenny for Thomas Highs, a reed-maker, of Leigh, in Lancashire, who, he says, completed the machine in 1763 or 1764, and named it after his daughter, whose Christian name was *Jane*. Mr. Baines, however, thinks that some confusion has been made between the jenny and the water-frame, which is said to have been invented by Arkwright, but most probably by Highs, as will appear hereafter. Highs, undoubtedly, made jennies at a later period, and also invented a double jenny with some new contrivances, which may have given rise to the belief that he was the original inventor. Other accounts say that the jenny was so named because it performed the work of a female.

A grandson of Hargreaves has furnished the writer with the following account of the origin of the word "Jenny." He received it from his Aunt Mary, who was one of Hargreaves's twelve children, and the first, except the inventor himself, who spun upon it. For two years after the invention she worked constantly at this machine, locked up in an upper chamber. Her mother on one occasion coming into the room, to see her spin, happened to remark, in allusion to her daughter's getting on well with her work, "Thou *gins* away famously!" The word *gin* (a contraction of *engine* according to Johnson) is applied to many machines, (such as the large drum or wheel worked by horses for drawing up out of a coal pit, &c.,) and the operatives always use the singular pronoun to their equals. Hence they spoke of the process of spinning on this machine as *ginning*, and subsequently the machine was called a *ginny*, and, eventually, was spelled *jenny*. Our informant further states, that the late Sir Robert Peel was the first person who was allowed to see the Jenny, the inventor exacting a promise that he would not divulge the secret. Sir Robert saw at once the immense value of the machine, and at length succeeded in persuading Hargreaves to apply for a patent.

of the spinning-wheel; its merit is its greater productiveness, and it is said to have occurred to him by one of those so-called accidents, which, when the mind is brooding on one particular subject frequently occur, and lead the thoughts in the right direction; or perhaps, we may rather say, that, at such a time, the mind is alive to the reception of any incident that may accidentally arise. Hargreaves had twelve children; and it is related that some of them and their playmates, were one day assembled at play, during the dinner hour, when a wheel at which he, or some member of the family, was spinning, was accidentally overturned: the thread still remained in the hands of the spinner, and as the wheel was prevented by the framing from touching the floor, it still continued to turn round, and to move the spindle as before, but in an upright instead of a horizontal position. Hargreaves surveyed this with mingled curiosity and attention; he expressed his surprise in loud exclamations, and continued again and again to turn the wheel as it lay on the floor with an interest which no one about him could understand. He had before attempted to spin with two or three spindles attached to ordinary wheels, holding the several threads between the fingers of the left hand, but the horizontal position of the spindles rendered the attempt ineffectual; and the thought had not struck him till now, that if a number of spindles were placed upright, and side by side, several threads might be spun at once. He therefore constructed a frame, in one part of which were placed eight rovings in a row, and in another part a row of eight spindles. The rovings, when extended to the spindles, were made to pass between two horizontal fluted bars of wood, forming a clasp, and acting in the place of as many fingers and thumbs as there were threads. This clasp opened and shut somewhat like a parallel ruler, and when pressed together held the threads fast. A certain portion

of roving being extended from the spindles to the fluted wooden clasp, this was closed with the left hand, and then drawn along the horizontal frame to a considerable distance from the spindles, the spinner at the same time with his right hand turning a fly wheel, which caused the spindles to move rapidly round. Thus, by giving the threads the requisite twist, at the same time that they were lengthened



HARGREAVES'S SPINNING JENNY.

out, the roving was spun into yarn. The threads were then thrown off the points of the spindles by a slight backward motion; and, being pressed down by a "faller," the yarn was then wound upon the spindles, (the quantity wound upon each spindle being termed a "cop.") On the clasp being returned to its first position it was again opened by a simple contrivance called a "knocker off," and then a fresh length of roving was drawn out and spun as before. The number of spindles mounted in one jenny was afterwards increased from eight to eighty.

Hargreaves was perfectly satisfied with the success of his invention, and would have been content to supply his own loom with weft without telling his neighbours by what means it was produced; for he

probably suspected that so powerful a rival would be regarded with envy and ill-will. This secret, however, was let out through the vanity of a female member of the family, who, on a visit to a sick friend, boasted of having spun a pound of cotton since her last visit shortly before. This was soon noised abroad, and excited so much surprise and ill-will among the spinners, that they broke into the poor inventor's cottage, destroyed the dreaded rival and most of his furniture with fire, and even threatened violence to Hargreaves himself. This compelled him to quit his native village, and he removed, in 1768, to Nottingham, where Mr. Thomas James, a joiner by trade, assisted him in erecting a small spinning-mill upon the jenny plan, where he spun yarn for the hosiers with considerable success. In 1770 he took out a patent for his invention, which was already beginning to be known and appreciated among manufacturers, and soon came to be extensively pirated in Lancashire. He therefore brought actions against them for damages, when a deputation was sent to him with the offer of 3,000*l.* for permission to use his machine. Hargreaves was unfortunately advised to refuse this offer, and to demand a larger sum. This was refused; the negotiation was broken off, and the actions proceeded; but, before they came to trial, Hargreaves' attorney was informed that, previous to the date of the patent, he had, under the pressure of poverty, mounted and sold several of his machines: this being sufficient in law to bar his claim to redress, the attorney abandoned the actions, and Hargreaves obtained no remuneration for an invention which at the time was really a national benefit. He died in 1778, not, as many writers state, in the deepest poverty and distress, for he left his family about 500*l.* The youngest and only surviving daughter of Hargreaves received, about three years ago, the sum of 250*l.* from the "Royal Bounty Fund," through the hands of Sir Robert Peel.

The spinning jenny soon spread through Lancashire, and supplied the long-felt deficiency of spinning hands, because by its means one woman could easily spin as much as had been formerly spun by twenty or thirty persons with the one-thread wheel. But the great and increasing demand for yarn soon reduced the spinning jenny to the same circumstances in which the distaff and spindle, and the one-thread wheel, were previously found; and the jenny was also destined to be superseded by more powerful and productive machinery, the history of which may now be briefly sketched.

SPINNING BY ROLLERS.—ARKWRIGHT.

In every kind of spinning, whether the material be cotton, flax, or wool, it is necessary to disentangle the fibres, to draw them out, and lay them side by side, before they can be twisted into threads. This is partially done by *carding*, by which the cotton is combed out into a sort of fleecy riband, called a *card-end*, or *sliver*. In this state, the fibres are very loose, and not laid so parallel with each other as they require to be in machine spinning. The sliver is therefore passed between two or more pairs of small rollers placed horizontally, the upper and lower roller in each pair revolving in contact. The sliver being put between the first pair of rollers, is drawn through and compressed, whereby a degree of firmness is given to it; it is then seized by the second pair, and is passed by them to the third. Now, if these three pairs of rollers all moved round equally fast, the only effect on the sliver would be to compress it; its length and substance remaining the same as before; but if the second pair of rollers be made to revolve three, four, or even ten times faster than the first pair, it is evident that the cotton must be drawn out three, four, or ten times smaller than when delivered from the first pair of rollers. By

passing the sliver through other pairs of rollers acting on the same principle, it is at length properly extended and compressed, and the fibres are laid parallel and continuous; the sliver is then connected with a spindle and fly, the rapid revolutions of which twist it into a thread, and then wind it upon a bobbin. The importance of these beautiful contrivances will be better seen hereafter; the present object being to complete the history of the cotton manufacture.

Sir Richard Arkwright is generally named as the inventor of the method of spinning by rollers. It has, however, been proved that the invention was the subject of a patent thirty years before Arkwright had even conceived it. The inventor, it is true, does not seem to have been aware of the value of his invention, for it was abandoned almost as soon as made; it was taken up by another mechanist, and again abandoned; it was attempted a third time, and succeeded; but the success was due in great measure to the genius of Arkwright, who improved upon the crude idea of the invention, (which was all that he seems ever to have received,) and to the steady perseverance with which he carried out and completed the idea amidst difficulties from which most men would have turned aside.

John Wyatt, of Birmingham, about the year 1738, invented a machine for spinning by rollers on the principle just explained, in which year it was patented in the name of Wyatt's partner, Lewis Paul, a foreigner. Wyatt's name appears only as a witness to the specification of the patent, but there is evidence that Wyatt was really the inventor. Cotton yarn was spun by this machine in 1741, and for a year or two afterwards; it was then given up. It was revived again, and a new patent taken out by Paul in 1758, but the success seems to have been small. In 1767, it is said that Highe, or Highs, made a machine on similar principles; that he employed a clockmaker, named Kay, to assist him in the brass

work, and that this Kay informed Arkwright of the invention, who immediately took it in hand, and with Kay's assistance succeeded in perfecting the machine.

Whether these particulars are strictly true as regards Highs may admit of some doubt; for they rest simply upon the evidence of Highs and Kay on a trial in which Arkwright's patent was disputed, in 1785. There is no doubt whatever on the subject of Wyatt's patent, for the specification is still in existence; and this deprives Arkwright of the claim to the original invention; but as his influence on the progress and prosperity of the cotton manufacture was all important, a sketch of his career may not be uninteresting in this place.

Richard Arkwright was born at Preston, in Lancashire, on the 23d December, 1732. He was the youngest of thirteen children, and, as his parents were poor, his education, as may be supposed, was of a very humble character. He was apprenticed to a barber, and at that time was scarcely able to write. Little or nothing is known of his early years, except that, in 1760, he set up in business for himself at Bolton, where he either discovered or read of a chemical process for dyeing hair; he therefore began to travel about for the purpose of collecting hair, which he dyed and disposed of to the wig-makers; a profitable occupation at that time, when wigs were so commonly worn. In 1761 he married a wife from Leigh, and the connexions he formed in that town are supposed to have led to much of his after knowledge. At any rate, living, as he did, in the midst of a manufacturing population, and travelling about from place to place, he must have frequently witnessed the shifts to which the weavers were exposed for want of a proper supply of yarn, and being himself of a mechanical turn, his mind would naturally be alive to any hints or suggestions for making the existing spinning machinery more productive. He was so fond of experiments in mechanics that he is said to have

injured his business in pursuing them. He was engaged in attempts to discover the perpetual motion, and employed Kay, the clockmaker, at Warrington, to bend some wires and turn some pieces of brass for the purpose; this was in 1767. During his frequent conversations with Kay, he became acquainted with Highs' scheme of spinning by rollers, and Kay states that he actually showed Arkwright a model of Highs' machine. Imperfectly as the principle of this machine was as yet developed, Arkwright appears at once to have felt its importance; for he abandoned everything else, and from this time devoted himself with wonderful constancy and perseverance to the perfecting and completing of the spinning-machine. He persuaded Kay to join him, not as partner, but as servant, and bound him in a bond to serve him at a certain rate of wages. Kay not being able to make the whole machine, Arkwright went with him to Mr. Peter Atheron, an instrument-maker, and asked him to complete it; but, from the poverty of Arkwright's appearance, he refused to do so; he agreed, however, to place at Kay's disposal a smith and a watch toolmaker, to make the heavier parts of the machine, and Kay was to make the clockmaker's part, and instruct the workmen. By these means Arkwright's first engine, for which he afterwards took out a patent, was made. Being destitute of money to prosecute his invention, he went to Preston, his native place, and applied to Mr. Smalley, the head-master of the Free Grammar School, for assistance, who, being convinced of the utility of the machine, at once gave it; and the spinning-machine was fitted up in the parlour of the house belonging to the school. It is mentioned as a proof of Arkwright's poverty, that having to vote at the contested election, which occurred during his stay in Preston, his clothes were in so tattered a condition, that a number of persons subscribed to put him in a decent plight to appear at the poll room.

Lest he should expose himself to the outcry against machinery which had been raised by Hargreaves' spinning jenny, Arkwright, accompanied by Smalley and Kay, removed to Nottingham, whither Hargreaves had gone before, so that this town became the nursery of the two most important inventions in the cotton manufacture. They applied to Messrs. Wright, the bankers, for a loan of money, which was granted on condition of sharing in the profits of the invention, but as the machine did not advance towards perfection so rapidly as the bankers wished, they recommended Arkwright to seek other assistance, and named Mr. Samuel Need, of Nottingham, the partner of Mr. Jedediah Strutt, of Derby, the improver and patentee of the stocking-frame, who, seeing Arkwright's machine, declared it to be an admirable invention, only wanting the better fitting of some of the wheels to each other. Both Need and Strutt immediately entered into partnership with Arkwright; the machine was soon perfected, and patented in 1769. In the specification, he says, that he "had by great study and long application invented a new piece of machinery never before found out, practised, or used for the making of weft or yarn from cotton, flax, and wool; which would be of great utility to a great many manufacturers, as well as to his Majesty's subjects in general, by employing a great number of poor persons in working the said machinery, and by making the said weft or yarn much superior in quality to any ever heretofore manufactured or made."

The partners now erected a mill at Nottingham for the new machines: the machinery was at first turned by horses, but this being found too expensive, they built another mill, on a much larger scale, at Cromford, in Derbyshire, which was worked by a water-wheel, and hence, the spinning-machinery was called the *water-frame*, and the yarn produced by it *water-twist*, a name which still continues to be applied to similar yarn.

The first great and important improvement intro-

duced by the new machine was the production of a firm hard thread fit for warps. Linen warps were now abandoned, and goods woven altogether of cotton were for the first time manufactured in this country. Calico, in imitation of the Indian fabric of that name, was also made.

The jenny was well adapted for weft spinning, so that the two machines were brought into use together, and aided and assisted each other.

The effect of these improvements in increasing the trade of the country, and multiplying and cheapening cotton goods for all classes of the people, might have been expected to ensure general favour and protection for them. It is painful to find that the Lancashire manufacturers were the first to oppose Arkwright's inventions: they combined together and refused to buy his yarns, although admitted to be superior to all others. His manufacture of calico was becoming every day of more importance, but this was suddenly stopped, in consequence of the officers of Excise refusing to let them pass at the usual duty of three pence per yard, insisting upon sixpence, as being Indian goods, although manufactured in England: when printed, the goods were prohibited altogether. A very considerable stock of goods thus accumulated, but they could not be sold, and the orders which were received every day could not be executed. Application to the Commissioners of Excise was without success. The partners, therefore, applied to Parliament for relief, which, after much expense, and in spite of a strong opposition of the Lancashire manufacturers, they obtained. An act was passed allowing the manufacture of calico, and to distinguish this from Indian or foreign calico, it was enacted, that "there shall be wove in the warp in both selvages, through the whole length thereof, three blue stripes, each stripe of one thread only," and stamped with the words *British Manufactory*.

For some years the manufacture was hindered by

the imperfections of the machinery employed to prepare the cotton for the water-frame. Arkwright exerted himself to improve these machines, and succeeded in making them worthy to be associated with the beautiful machine which had cost him so much anxiety. Indeed, the whole of the cotton manufacture is indebted to him for a large number of valuable improvements, if not inventions; and those who rest his fame solely upon the invention of spinning by rollers are but little acquainted with his genius. He was the first person that ever erected a cotton-mill, and formed a distinct idea of all the processes that were to be carried on within it. He was able, in one view, to see all the changes which the fibres must undergo from the tangled wool to the finished thread, and when any imperfection was discovered in his yarn, he could in a moment state which of the processes through which it had gone was the cause of the defect.

The carding of cotton had hitherto been performed in a very rude manner by *hand*-cards, as already described. The first great improvement in this process was the introduction of the "stock-cards," used in the woollen manufacture. These were of much larger size, and one of them being fixed to a table, while the other was hung from the ceiling, a greater quantity of work was produced with more ease to the carder. In 1748, the first grand step towards the present carding-machine was made by Lewis Paul; but the merit of perfecting it belongs to Arkwright. He combined the various improvements made by other men, added some of his own, and produced a complete machine, so well calculated for the purpose, that the principle has not been improved upon to the present day.

The various admirable contrivances of Arkwright will be better understood when we enter upon the details of the manufacture. It will be sufficient here to state, that in December 1775, he took out a second

patent for a series of machines, including carding, drawing, and roving machines, which he claimed as his own. Each machine was probably a skilful combination of the separate inventions of other men; but the effect on the cotton manufacture was not the less decided. Yarn could now be had in any quantity, and at a price lower than it had ever been known. The shuttle flew with fresh energy; weavers earned high wages, and fresh spinning-mills were erected to supply yarn. The fame of Arkwright was completely established; numbers of manufacturers flocked to buy his patent machines, or licences to use them. In 1782, it was calculated that upwards of five thousand persons were employed in the manufactories of Arkwright and his partners alone.

The origin of the factory system is generally referred to this period, although a few silk-mills had existed from the time of Sir Thomas Lombe, who, in 1719, erected a mill on the Derwent, at Derby, on the model of those he had seen in Italy. Hitherto cotton had been prepared at the homes of the workmen, with such simple machines as the hand or stock cards, the spinning-wheel, and the loom. This was part of the ordinary furniture of the cottages of the manufacturing districts. When the spinning jenny got into use, and the number of spindles was greatly increased, a workshop was added to the cottage. But Arkwright's machines required more space than a cottage could furnish, and more force than the human arm could supply; their weight also needed strongly built mills, which it was found could not be worked to advantage except by water-power, (for the steam-engine of Watt was not yet perfected); the improvements in them had also introduced a greater number of processes, and a more marked division of labour.

Arkwright's first mill, built in 1771, at Cromford, was described by Dr. Darwin, in the following poetical language:—

"Where Derwent guides his dusky floods,
Through vaulted mountains and a night of woods,
The nymph *Gossypia* treads the velvet sod,
And warms with rosy smiles the wat'ry god;
His pond'rous oars to slender spindles turns,
And pours o'er massy wheels his foaming urns;
With playful charms her hoary lover wins,
And wields his trident while the Monarch spins.
First, with nice eye, emerging Naiades cull
From leathery pods the vegetable wool;
With wiry teeth *revolving cards* release
The tangled knots, and smooth the ravell'd fleece:
Next moves the *iron hand* with fingers fine,
Combs the wide card, and forms th' eternal line;
Slow with soft lips the *whirling can* acquires
The tender skeins, and wraps in rising spires:
With quicken'd pace *successive rollers* move,
And these retain, and those extend, the *rove*:
Then fly the spokes, the rapid axles glow,
While slowly circumvolves the labouring wheel below."

The triumphant success of Arkwright excited the jealousy of his fellow-manufacturers; and, as the idea was very common in Lancashire that he was not really the inventor of the various machines for which he had obtained patents, many manufacturers set up his machines without obtaining his licence. To vindicate his claims, he brought nine actions against as many persons in 1781. The Lancashire spinners formed an association among themselves to defend these actions, only one of which came to trial, and that was for infringing the second patent. The defence was confined to a single point,—namely, that the specification, or description of the invention, which he had enrolled, did not comply with the terms required by law,—that it should contain such a full and clear account of the invention as would enable any one to take advantage of it, after the expiration of the term for which the patent was granted. On this ground a verdict was given for the defendant; the other actions were then abandoned, and thus this profitable patent was thrown open to the public.

For a long time Arkwright allowed this verdict to remain undisputed; but, conceiving he had a claim to

a national reward for the great inventions which he had perfected, he published a pamphlet, entitled, "The Case of Mr. Richard Arkwright and Co., in relation to Mr. Arkwright's Invention of an Engine for spinning Cotton, &c. into Yarn; stating his Reasons for applying to Parliament for an Act to secure his Right to such Invention, or for such other Relief as to the Legislature shall seem meet." In this pamphlet he urged his claim to the invention of the several machines already noticed; spoke of his successful efforts to establish a new system of spinning, and his introduction of the calico manufacture in spite of opposition and jealousy; all which entitled him to the gratitude of the nation. He then spoke of his wrongs; the extensive piracy of his machines; and contended that it could not be supposed that he meant a fraud on his country by the obscurity of his specification. On the contrary, his object was to benefit his country by preventing the introduction of such important machines into other countries; "in preventing of which evil, he had purposely omitted to give so full and particular a description of his inventions in his specification as he otherwise would have done." He prayed that the Legislature would "confirm, connect, and consolidate the two letters patent, so as to preserve to him the full benefit of his invention for the remainder of the term yet to come in the last patent." In this request, he was, in fact, asking for an immense reward,—no less than the patent right of all the machines, which were now most extensively used, to be continued to him for eight years longer. He did not, however, apply to Parliament; probably, because he knew that success was hopeless; but he no doubt thought to engage the public sympathy in his favour by the publication of his case.

In 1785 he again sought to establish his second patent, by bringing an action for its infringement. The cause was tried in the Court of Common Pleas,

and he endeavoured to show that the machines were sufficiently described in his specification. The judge, Lord Loughborough, also supporting this view, Arkwright obtained a verdict. This excited considerable alarm among the Lancashire spinners, who immediately applied to the Lord Chancellor for a writ to try the validity of the patent. This was granted, and the cause came on in the Court of King's Bench, on the 25th of June, 1785, before Mr. Justice Buller and a special jury. The patent was opposed on four grounds:—1. That it was a great inconvenience to the public. 2. That the inventions were not new at the time when the patent was granted. 3. That Arkwright had no claim to the inventions; and 4. That he had not disclosed the inventions in the specification. These grounds were supported by a number of witnesses, among whom where Highs and Kay, to prove that the former had invented the spinning by rollers, which had been communicated to Arkwright by the latter. Thus, a strong case was made out against the patent, which was but feebly met by Arkwright; his patent was therefore set aside, and his application for a new trial refused.

It has been already stated that Wyatt was the original inventor of spinning by rollers: but there is no evidence that Arkwright had ever seen or heard of Wyatt's machine, which, although it deprives Arkwright of his claim to the invention of the principle, also deprives of that honour the men upon whose evidence Arkwright lost his cause. It is not denied that Wyatt's machine and Highs' model were very imperfect, and that Arkwright had to perfect the details, and make the invention practicable and profitable. Whatever the merits of the case may be, there can be no doubt that the setting aside of the patent was a great national advantage; for the manufacture soon acquired an extent and importance which could not have occurred had it continued to be a monopoly. Arkwright himself had his full share in

the general prosperity: his numerous concerns were managed with great skill, and wealth poured in upon him from all sides. During several years he fixed the price of cotton twist, and all other spinners conformed to his prices. Honours, too, were not wanting. In 1786 he was appointed high-sheriff of Derbyshire, and having to present an address of congratulation from that county to his Majesty King George the Third, on his escape from the attempt of Margaret Nicholson on his life, he was knighted. He died at his house at Cromford, 3d of August, 1792, in the sixtieth year of his age.

In estimating the character of Arkwright, Mr. Baines is inclined to think that his inventive talents have been over-estimated. "In improving and perfecting mechanical inventions; in exactly adapting them to the purposes for which they were intended; in arranging a comprehensive system of manufacturing, and in conducting vast and complicated concerns, he displayed a bold and fertile mind, and consummate judgment, which when his want of education, and the influence of an employment so extremely unfavourable to mental expansion as that of his previous life are considered, must have excited the astonishment of mankind. * * * The most marked traits in the character of Arkwright were his wonderful ardour, energy, and perseverance. He commonly laboured in his multifarious concerns from five in the morning till nine at night, and when considerably more than fifty years of age,—feeling that the defects of his education placed him under great difficulties and inconvenience in conducting his correspondence, and in the general management of his business,—he encroached upon his sleep in order to gain an hour each day to learn English grammar, and another hour to improve his writing and orthography."

THE MULE JENNY.—CROMPTON.

WHILE Arkwright was pursuing his prosperous course, another untaught genius was working in obscurity to produce a machine, which in productive power, and quality of work, has rivalled, and even surpassed the water-frame.

When the cotton-spinners attempted to produce fine qualities of yarn, the machines of Hargreaves and Arkwright were found to be not well adapted for the purpose. The water-frame spun twist for warps; but the pull of the rollers broke thread of fine quality, while winding itself upon the bobbins. The happy thought occurred to a weaver, of the name of Samuel Crompton, that by combining the principles of the roller spinning of Arkwright with the jenny spinning of Hargreaves, the objections which applied to them separately might be got rid of. By a perfectly original contrivance this union was effected, and the machine resulting from it was called "the mule," or "the mule jenny." Its distinguishing feature was that the spindles instead of being stationary, as in both the other machines, were placed on a moveable carriage, or "mule," which was wheeled out to the distance of about five feet, in order to stretch and twist the thread, and wheeled in again to wind it on the spindles.

The author of this invention lived at a beautiful and retired spot near Bolton, called Hall-in-the-Wood. He was not above twenty-one years of age when he began to think about his invention. He had no sooner formed a clear idea of it in his own mind, than he proceeded to execute it himself, with such tools as he could afford to purchase out of his little earnings. The machine was completed in 1779. "At the end of the following year," he says, "I was under the necessity of making it public, or destroying it, as it was not in my power to keep it and work it; and to destroy it was too painful a task, having been four and a half years, at least, wherein every moment of

time and power of mind, as well as expense, which my other employment would permit, were devoted to this one end, the having good yarn to weave; so that to destroy it, I could not."

It appears, then, that the object of the inventor of this beautiful contrivance was merely to supply his own loom with good yarn; he took out no patent, and only regretted that public curiosity would not allow him to enjoy his little invention undisturbed in his attic: but the very superior quality of his yarn attracted persons from all quarters to see how he produced it, and they even climbed up to his windows to watch him at work. He erected a screen to prevent this, but the annoyance was so great, that he found it impossible to enjoy the fruits of his labour in quiet; he was, therefore, induced to lay the whole thing before a number of gentlemen and others, who subscribed a guinea each to look at it. He thus raised about fifty pounds, which enabled him to construct another machine, which was larger and more perfect than the first.

Crompton's machine was for some time called the "Hall-in-the-wood wheel," and also the "muslin wheel," because it made yarn fine enough for muslins. Indeed, at a time when no other machinery could produce yarn of more than forty hanks to the pound, Crompton spun eighties.*

* Yarn is named after the number of hanks, each containing 840 yards, which weigh a pound. In Crompton's time, eighty hanks to the pound was thought a wonderful achievement; but such has been the improvements in the machinery, that Mr. Houldsworth, of Manchester, has produced yarn of the number 460. So that, 460 hanks in the pound, at 840 yards to the hank, gives a length of 386,400 yards, or nearly 220 miles. This, however, is an unusually high number; 300 being the usual limit of fineness.

It is also remarkable to notice the effect of improved machinery on the prices of the yarn. Crompton received fourteen shillings per pound, for the spinning and preparation of No. 40; he afterwards got twenty-five shillings for No. 60, and he spun No. 80 at forty-two shillings.

At the present day, No. 100 is commonly produced at from two shillings and three-pence to three shillings the pound, including from ten-pence to twelve-pence, the cost of the raw material. But for such high numbers as 460, the yarn is worth more than a guinea an ounce.

As Crompton's invention was not protected by any patent, it was used not only by the great manufacturers of his neighbourhood, but soon by weavers, and also by persons who had no connexion with spinning or weaving. "The art of spinning on Crompton's machine," says Mr. Kennedy, "was tolerably well known, from the circumstance of the high wages that could be obtained by those working on it above the ordinary wages of other artizans, such as shoemakers, joiners, hatmakers, &c., who on that account left their previous employment; and to them might be applied the fable of the town in a state of siege. For if in the course of their working the machine there was any little thing out of gear, each workman endeavoured to fill up the deficiency with some expedient suggested by his former trade. The smith suggested a piece of iron, the shoemaker a welt of leather, &c., all which had a good effect in improving the machine. Each put what he thought best to the experiment, and that which was good was retained."

Although the mule was thus getting into extensive use, yet the inventor did not profit by the immense advantages it was conferring on the manufacture. In the year 1812, however, some gentlemen of Manchester got up a memorial to Government, which was numerously signed, stating Crompton's claims, and the result was a parliamentary grant of the clear sum of 5,000*l.* He employed this in establishing his sons in the bleaching business; but from various unfortunate circumstances they failed, and Crompton was again reduced to poverty. His friend and biographer, Mr. Kennedy, again exerted himself to raise a subscription, with which a small annuity was purchased; but he did not live to enjoy it more than two years. He died in the year 1827.

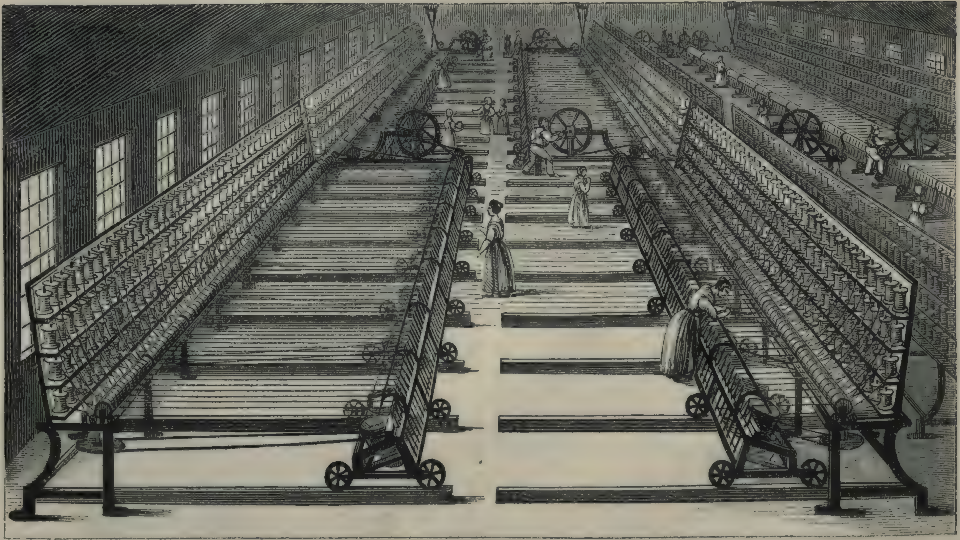
Crompton's first mule did not carry more than twenty or thirty spindles; double mules are now sometimes made carrying 1,100 each, or 2,200 the pair; one spinner being competent to manage them. Indeed, the mule is capable of doing so

much work that it seemed likely at one time to supersede all other methods of spinning; but when the power-loom came into use, twist for warps was required of that superior strength and wiry smoothness which the water-frame produced; it was therefore remodelled, and a simpler and improved machine produced, requiring less power to drive it than the water-frame. The new machine was called a *throstle,* probably from its singing sound.

The progress of improvement has been such, that *self-acting mules* are now constructed. Mechanism rolls the spindle-carriage out and in at the proper speed, and winds the yarn on the cops; the only manual labour required being to join the broken threads, and keep the machine in order.

There are other machines and contrivances now in use in the cotton manufacture, which will be noticed as we go through the process. The spirit of improvement is so untiring, that it has been impossible in this brief sketch to do more than notice a few of the most distinguished inventors who led the way, and made the path of improvement easy to their successors.

HALL-IN-THE-WOOD, NEAR BOLTON.



MULE SPINNING.

THE

MANUFACTURE OF COTTON YARN.

PART II.

THE locality of a manufacture is usually determined by the facility with which water-power, fuel, and iron can be obtained; for, where they are abundant, machinery can be made and put in motion at small cost: and, in this respect, many parts of Lancashire and its neighbourhood are highly favoured. There is perhaps no spot of ground in the world more advantageously situated for manufactures than the tract lying between the Ribble and the Mersey. The neighbouring hills pour down a number of rapid streams, which furnish water-power to many hundred mills, feed navigable canals, supply water for scouring, bleaching, printing, dyeing, and other processes. The river Irwell is said to be "the hardest worked river in the universe;" for, besides washing, bleaching, dyeing, &c., it is calculated to move, with its tributaries, not fewer than three hundred water-wheels, some of which are of very large size. South Lancashire is rich in coal fields, which are worked with great ease and economy; the neighbouring counties furnish abundance of iron; the great sea-port of Liverpool supplies the raw material, and exports the beautiful fabrics produced in this industrious district.*

Here it is that the cotton factories are principally situated,—those stupendous buildings which fill the

* A considerable quantity of manufactured cotton goods is also exported from the ports of London, Hull, Bristol, and Newcastle-upon-Tyne.

mind with astonishment, until their internal arrangements are inspected and understood, and then with admiration and delight. Whether the power be steam or water, the plan of the building is the same. A cotton factory is a huge square structure, often containing seven or eight stories, the rooms of which may be two or three hundred feet in length, lighted by numerous windows, which have a singularly picturesque appearance by night, when seen from without. "The operations carried on within its walls," says Mr. Baines, "are numerous, and every one of them is performed by machinery, without the help of human hands, except merely in transferring the material from one machine to another. It is by iron fingers, teeth and wheels, moving with exhaustless energy and devouring speed, that the cotton is opened, cleaned, spread, carded, drawn, roved, spun, wound, warped, dressed, and woven. The various machines are proportioned to each other, in regard to their capability of work, and they are so placed in the mill as to allow the material to be carried from stage to stage with the least possible loss of time. All are moving at once, the operations chasing each other; and all derive their motion from the mighty engine, which, firmly seated in the lower part of the building, and constantly fed with water and fuel, toils through the day with the strength of perhaps a hundred horses. Men, in the mean while, have merely to attend on this wonderful series of mechanism, to supply it with work, to oil its joints, and to check its slight and unfrequent irregularities; each workman performing, or rather superintending, as much work as could have been done by two or three hundred men sixty years ago. At the approach of darkness, the building is illuminated by jets of flame, whose brilliance mimics the light of day, the produce of an invisible vapour generated on the spot. When it is remembered that all these inventions have been made within the last seventy years, it must be ac-

knowledged that the cotton mill presents the most striking example of the dominion obtained by human science over the powers of nature, of which modern times can boast. That this vast aggregate of important discoveries and inventions should, with scarcely an exception, have proceeded from English genius, must be a reflection highly satisfactory to every Englishman."

SORTING THE COTTON, WILLOWING, BATTING, BLOWING, AND LAPPING.

THE importers of cotton employ certain brokers in Liverpool, who set a value upon the sample, and find purchasers to any amount. The buyers, who are the spinners all over the country, and the Manchester cotton dealers, also employ brokers to make their purchases. The brokers charge, both to seller and buyer, a commission of ten shillings for every hundred pounds worth of cotton.

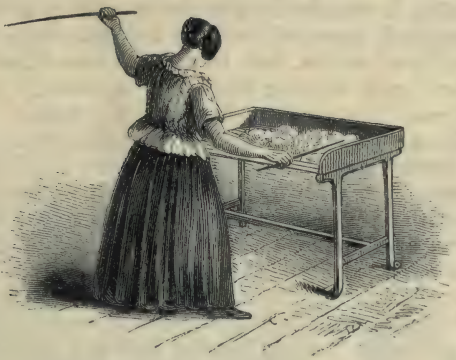
The cotton is seldom unpacked until it arrives at the mill, the purchases being all managed by samples. When it is unpacked, the first thing to be done is the sorting, and in this much care and skill are required; for the different bags furnish different qualities of cotton, and it is necessary to produce yarn of uniform quality, at the cheapest rate. In order, therefore, to equalize the different qualities, the contents of all the bags are mixed together in the following manner. A space being cleared and marked out on the floor, the cotton contained in the first bag is scattered over this space, so as exactly to cover it; the contents of the second bag are, in like manner, spread over the first, and the cotton in all the other bags is disposed in a similar manner; men and boys tread down the heap, which is called a *bing* or *bunker*, until at length it rises up in shape and dimensions very much like a large hay-stack. Whenever a supply of cotton is

taken from the bing, it is torn down with a rake from top to bottom, by which means it is evident the contents of the different bags are collected together in a mass of uniform quality and colour. In mixing different qualities of cotton, it is usual to bring together such only as have a similar length of staple. A portion of the waste cotton of the mill is also mixed in the bing, for making the lower qualities of yarn. For higher numbers, as well as for warps, a finer quality of cotton must be selected; and thus it will be seen that the formation of the bing is an important operation, the quality of the goods produced depending upon it.

In this state the cotton contains sand, dirt, and other impurities, and the fibres are matted together by the pressure they were subjected to in packing. To open the fibres, and get rid of the sand, &c., the cotton is put into a machine called a *willow*. This consists of a box or case, containing a conical wooden beam, studded over with iron spikes: this beam is made to turn round five or six hundred times in a minute. The cotton, as it is torn down from the bing, is put in at one end of the machine, where it is caught by the spikes, tossed about and shaken with great violence, and gradually driven forward to the other end. The sand and other heavy impurities fall out of the machine, through an open grating at the bottom; the dust and lighter matters pass off through a series of wire openings, and the cleaned cotton is sent down a shoot into the room below.

If the cotton is of fine quality, it is beaten, or *batted*, with hazel or holly twigs. For this purpose, it is spread upon a frame, the upper part of which is made of cords, and is quite elastic. A woman, with a rod about three or four feet long in each hand, beats the cotton with great violence, producing a similar effect to the bow-string of the Hindoo. Any loose impurities which remain fall out between the cords;

seeds, and fragments of seed-pods, which adhere to the cotton somewhat firmly, are picked out by hand. By this method, the tangled locks disappear, the cotton is thoroughly opened, and made quite clean, without injuring the staple.



BATTING.

The coarser qualities are passed at once from the willow to the *scutching* or *blowing* machine, which does the work of batting, only in a more violent manner, and is, therefore, not adapted for fine qualities; but, in coarser spinning, is in general use to prepare the cotton for the carding-engine, as was the case at one of the mills visited by the writer. The cotton, as it was shot down from the willow, was received upon an endless band, called a *creeper*, ingeniously covered with laths of wood moving upon rollers: it supplied cotton to the various blowing-machines placed at equal distances across a long room. Each machine was attended by two lads, one of whom weighed a portion of the cotton, while the other spread it upon an endless band employed to feed the machine. This band was also formed of laths, placed crossways and fastened together, in

preference to cloth, which is apt to sink along the middle, and thus feed the machine irregularly. Two or three of the laths were painted black, for the purpose of dividing the surface of the feeder into two or three equal parts. The feeder being constantly urged, with a slow motion, towards the mouth of the machine, it was the duty of the attendant, as soon as a black lath appeared, to begin to spread the weighed quantity of cotton, and to make it cover the whole surface until another black lath appeared: he was then ready to spread another weight of cotton. Thus, while one part of the feeder is constantly supplying the insatiable appetite of the machine, another part returns for a fresh supply. As soon as the cotton enters the jaws of the machine, it is seized by two rollers, and immediately exposed to the blows of a *batting-arm*, or beater, which is turned round with great velocity within a kind of drum, of which the arms of the beater form the diameter. The solid impurities fall through a grating, but the dust and lighter matters are sucked up through a shoot, in which the air is rarefied by a revolving fan. The wind produced by the batting-arm drives the light cotton filaments onward, where they are assaulted by another batting-arm: they are again urged forward, and blown with tolerable regularity over the surface of a wire-gauze drum, which is constantly revolving. Beneath this drum, and in close contact with it, is an endless band moving on rollers, which receives the cotton, and conveys it out of the machine. The pressure of the drum upon the band condenses the cotton into a filmy sheet; that is, the fibres cling together sufficiently to allow the cotton to be wound upon an iron rod as it leaves the machine, and in this state it is called a *lap*. The advantage of this is, that a uniform thickness can be presented to the carding-engine, which is a necessary condition.

In spinning fine yarns, this method of preparing the laps does not answer so well as forming them by

hand. This practice was introduced by Arkwright, and it is done in various ways. In Mr. Houldsworth's mill, at the time of the writer's visit, the following method was adopted:—A boy was furnished with two qualities of cotton, contained in separate baskets: from one of these he took a certain quantity, and put it, together with a weight which hung from the beam of the scale, into the pan until the scale went down; the weight was then taken out, and its equivalent

FORMING LAPS BY HAND.

made up from the second basket.* The cotton thus weighed was taken to a canvass strip, one half of which was extended along a kind of frame near the wall, while the other half rested on the floor. The

* By this method cotton of various degrees of fineness may be mixed in any proportion. Suppose, for example, the manufacturer wishes to produce yarn from two qualities of cotton in the proportion of 3 of one to 2 of the other. The large scale weight will be $1\frac{1}{4}$ or $\frac{5}{4}$. He first puts a small weight equal to $\frac{1}{2}$ into the scale pan, with the first lot of cotton, and thus gets $\frac{3}{4}$ of the quantity required; then taking out the weight he adds cotton from the second basket, to the value of $\frac{2}{4}$ or $\frac{1}{2}$.

lad distributed the cotton over this cloth, batting

FANS USED IN BATTING AND LAPPING.

and slightly raising it with a rod, and then flattening it with a kind of fan formed by the union of five rods. The boy then rolled upon an iron spindle the portion of the cloth covered with cotton, and, in doing so, dragged upon the frame the remaining half, which was in like manner covered with cotton, and rolled up. The laps thus formed were placed in a heap in the lower part of the frame, ready for the carding-engine. In forming these laps the greatest precision is required, because the size of the yarn to be produced depends upon the quantity of cotton spread over a given surface, and any irregularity in the spreading is likely to interfere with the uniform thickness of the yarn. As the cotton varies slightly in weight, according as the weather is wet or dry, it is sometimes usual to weigh it with a cotton weight, formed by packing a quantity of cotton into a hollow copper tube or ball, pierced with holes. As this weight is about as much affected by changes in the weather as the cotton itself, an equality is thus preserved in forming the laps.

CARDING.

The cotton, which is still in a confused and tangled state, has now to be carded, upon the regularity and perfection of which process depends much of the success of spinning, and also of the beauty and durability of the stuff to be woven. It has been already explained, that a cotton card is a sort of brush, containing wires instead of bristles. The cards are made of bands or fillets of leather,* pierced with

* By a recent improvement, the cards are formed of alternate layers of cotton, linen, and Indian-rubber.

numerous holes, in which are fixed bent pieces of iron wire, called dents or teeth. Each piece of wire, by being bent, forms two teeth; thus:  These must be of equal size and shape; they must stand at equal distances, and be equally inclined to the curved surface of the drum, round which the cards are to be lapped. The leather must also be of the same thickness throughout, or the teeth will not stand at precisely the same height.

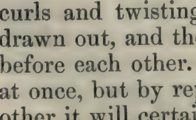
When cards were made by hand, it was quite impossible to comply with these conditions, all of which are necessary to good carding. Much ingenuity has been exercised in producing a *card-making machine*, which the writer had an opportunity of inspecting at the works of Messrs. Curtis and Co., at Manchester; but it would be impossible, in this little treatise, to give more than a general idea of this wonderful piece of mechanism. The leather is first prepared by a machine, which cuts it into sheets and fillets of the proper length and breadth; each fillet is wetted and stretched to its full extent, so as to produce an even surface; it is then passed between rollers, against a nicely-adjusted knife-edge, which shaves it down to a perfectly uniform thickness. The fillet is then wound upon a roller, and made to pass between two guide-rollers, to a receiving-roller above the card-making machine, when the fillet is held fast, and stretched by a clamp. The wire of which the teeth are to be made is supplied from a drum placed at the side.

Matters being thus arranged, the machine performs its work in the following order:—Two prickers advance, and make two holes in the surface of the leather; a pair of sliding pincers next seize the wire, and wind off from the drum a length exactly sufficient for two teeth; a tongue of steel holds this piece of wire exactly in the middle, while a knife advances and cuts it off from that part of the wire held in the pincers. Steel fingers next advance, bend the piece of wire just cut off, and carry it

forward to the holes previously made by the prickers. The points of the wire are seized on the opposite side of the leather, and a bar rises up and bends the two limbs so as to form a knee in each. A pusher then acts from the opposite side, and drives home the wire into the leather, which is then shifted by the guide rollers, and another wire is inserted as before.

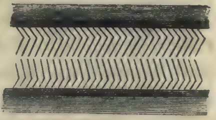
When this machine works at its ordinary speed, it is quite impossible to follow its various complicated movements, for it puts in two hundred teeth every minute, completing a length of twenty feet of card in a day; but the superintendent was so kind as to put the machine out of gear with the steam engine (which works ninety card-making machines in one room), and to turn it slowly by hand, whereby its beautiful movements were made intelligible. What adds apparently to the complexity of the machine, is the necessity of making cards for some purposes *ribbed*, that is, arranging the wires in lines crossing the fillet; while for other purposes the cards are *twilled*, that is, the wires form oblique lines across the fillet. When the cards leave this machine, all slight inequalities are removed by grinding; and the cards, when in use, are ground down from time to time, sometimes every day, until worn out.

The appearance of the cards, and their mode of action, will be understood from the following figure.

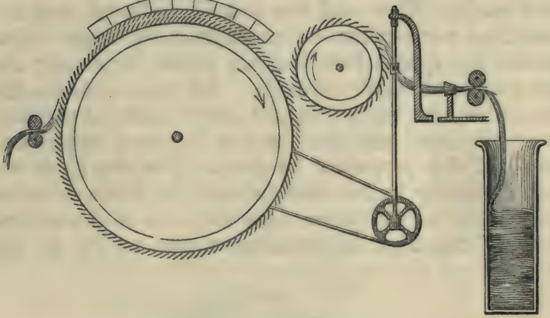


If these cards be moved in opposite directions with a tangled tuft of cotton between them, the fibres will be seized by all the teeth—those of the top card will pull them one way, those of the bottom another, by which means all the curls and twistings of the lock will be opened and drawn out, and the fibres made to lie side by side, or before each other. This effect may not be produced at once, but by repeatedly drawing one card over the other it will certainly be effected.

But in thus laying the fibres side by side, and end to end, each card takes up a portion of the cotton. To get the whole of the cotton upon one card, all that is necessary is to reverse the position of the two, and to place them as shown in the opposite figure, where it will be seen that by drawing the upper card over the lower one, the teeth of the latter can offer no resistance, and thus it is stripped of its cotton.



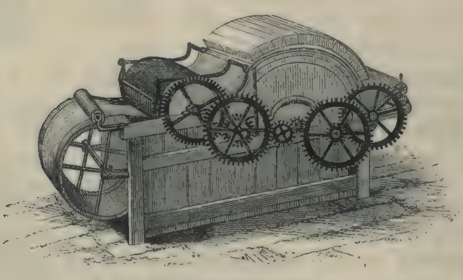
In the carding-engine this principle is carried out on a large scale. A drum about three or four feet



in diameter, and three or four feet in length, moving on a horizontal axis, is covered with narrow fillet cards parallel to the axis, a small space being left between the separate fillets. The upper part of the drum is covered with a concave frame, containing narrow cards, corresponding in form to those of the cylinder. The cotton lap is supported at one end of the engine upon a roller, which, by slowly turning, assists in unfolding it. As it becomes unfolded, it passes between two fluted rollers, which are pressed together by a weight hanging from the end of the upper roller. The cotton is then

caught by the wires of the main cylinder, the teeth of which, assisted by the cards of the frame-work, arrange the fibres of the cotton, as already explained. After this they are taken off by a second cylinder, called a *doffer*, which moves in a contrary direction, and from this the cotton is removed by a very beautiful contrivance, called the *crank and comb*.

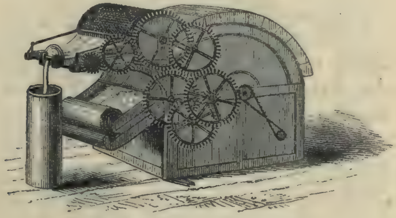
The inventor of the carding-engine is not known with certainty. It appears, however, that in 1748, Lewis Paul patented two different machines for carding, in one of which the cards were arranged on a flat surface, and in the other on a drum. The cards were arranged parallel to each other and to the axis of the drum, a space being left between every two cards. The wool was put on by hand, and the cardings were taken off separately by a moveable comb, the spaces between the cards regulating the substance of each carding. By this method the machines had to be stopped every time the cardings were taken off, and then had to be joined end to end to form the perpetual carding. The machine was not generally known and adopted in Lancashire for more than twenty years after the date of the patent. One of the first improvements was to fix to the



FIRST CARDING ENGINE.

machine a revolving cloth or feeder, on which a given weight of cotton wool was spread, by which it

was conveyed to the machine. Arkwright further improved this by rolling up the feeder with the cotton spread upon it, as already explained, and allowing this gradually to unroll to feed the cylinder. Another improvement brought off the carded wool in a continuous fleece, forming a uniform and perpetual sliver. The doffer, which strips the wool from the large cylinder, turned off a carding of no greater length than that of the cylinder; but it was found, that by entirely covering the doffer with narrow cards, wound round in a spiral form, without having any spaces, the wool might be brought off in one unbroken fleece. But the method of stripping off the wool from the doffer was attended with many difficulties, which were at length overcome by the invention of the crank and comb. A plate of metal, finely toothed like a comb, is worked by a crank up and down over the doffer, so that, by slight and frequent strokes on the teeth of the card, it strips off the cotton in a continuous filmy fleece, which, as it comes off, is drawn through a funnel at a little distance in front of the cylinder, which reduces it to a roll or *sliver*. This after passing between two rollers, and, being compressed into a firm, flat riband, falls into a deep can, where it is coiled up in a continuous length until the can is filled.



SECOND CARDING ENGINE.

The invention of the crank and comb has been given by some to Arkwright; by others to Har-

greaves, the inventor of the jenny. Those who defend the claim of the former, say that it was communicated to Hargreaves by one of Arkwright's workmen, who chalked out a sketch of it upon the table of a public-house.

Thus, by a series of ingenious improvements, the carding-engine was perfected, and it has scarcely been improved since Arkwright's time. It is interesting to watch the cotton at one end in its tangled, knotted state, the fibres lying in every direction, and then to walk to the other end and notice the beautiful filmy web stripped from the doffer by the crank and comb. It is so light and flimsy that it no longer resembles cotton, but rather the delicate lines which the gossamer spider sometimes draws over the fields in autumn.

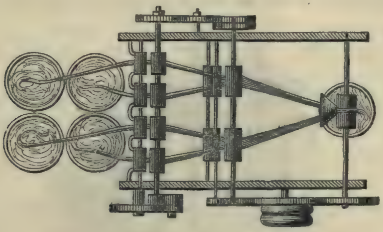
In fine spinning, the cotton passes through two carding-engines; the first a coarse, and called a *breaker-card*, and the second, in which the teeth are finer, called a *finishing-card*. A number of cardings from the breaker-card are united together at the edges by passing them between the steel rollers of a *lap-machine*; the new lap thus formed is wound upon a cylinder, and is then ready to feed the finishing-card.

DOUBLING AND DRAWING.

The fibres of the cotton are not yet sufficiently level to be twisted into yarn; and it often happens that the teeth of the card lay hold of a fibre by the middle, and thus double it together, in which state it is unfit for spinning. The cardings are therefore doubled and drawn out by a machine called the *drawing* frame, the principle of which depends upon different pairs of rollers revolving with different degrees of rapidity, as already noticed. If, however, the riband, as it leaves the carding-engine,

were simply extended in length by drawing it out, it would be liable to tear across, or to be of a different thickness at different parts of its length. To prevent the tearing, and to equalize the thickness, a number of cardings are joined together, and drawn out to a length equal to the sum of the lengths of all the separate cardings. The effect produced is the same as taking a piece of cotton-wool between the finger and thumb, and drawing it out many times, laying the drawn filaments over each other, before each drawing. If the cotton be then examined, it will be found that all the fibres are parallel, and of equal length. This effect is accomplished very perfectly in the drawing-frame, which consists of a number of rollers, arranged in what are called *heads*, each head consisting of three pairs of rollers, of which the second pair moves with greater speed than the first, and the third moves quicker than the second. Drawing rollers are used in several machines which have yet to be noticed; their arrangement and mode of action may therefore be further explained.

The accompanying figure represents the arrangement of one drawing-head. The under rollers are



made of iron and fluted; the upper ones, also of iron, are smooth, and covered first with flannel and then with leather. This enables the rollers to take firm hold of the cotton. The top rollers are sometimes called *pressers*, because they press, by means of weights, upon the under ones. These weights are

hung to a curved hook, or to a saddle, which includes two or more rollers. A mahogany bar, faced with flannel, rests, by its own weight, upon the top rollers, and strips off all the loose, hanging fibres. Similar bars are also made to press up against the under fluted rollers. The distance between the first and second pairs of rollers is never allowed to exceed the length of the cotton filaments, for if such were the case, the riband might be torn apart by the second pair pulling it while the first held it fast. The riband is stretched most in passing from the second to the third pair, the distance between which must not be too great, for the reason just stated, nor too small, or the staple will be torn.

The cardings are sometimes presented to the drawing-frame in the form of laps, or more usually they are taken up from separate cans, and guided over a tin or brass plate containing a number of separate channels. They all meet and unite together just before passing between the first pair of rollers, which reduces them all into one sliver; the second pair extends every inch of this compound sliver into about two inches, and the third pair of rollers extends these two inches into ten: so that, suppose ten slivers from

DRAWING. (12 INTO 1.)

ten separate cans enter the frame on one side, the result is, that, after passing through the rollers, a single sliver is produced of the same thickness as one

of the ten slivers, but of ten times the length; the ten slivers are, in fact, united into one, and this being passed between two smooth cast-iron rollers, to condense it, is allowed to fall into a can on the opposite side of the frame.

By repeating this process again and again, it will be easily seen that the chances of uniformity in the sliver are greatly multiplied; for the defects of individual slivers are absorbed and got rid of. When ten of the cans are filled with the compound sliver, they are passed on to a second drawing-head, and the ten *drawings*, as they are now called, are again doubled, and drawn out into one. Twelve of these are then doubled, and drawn out at a third head; twelve of these are doubled again, and again drawn out at a fourth head; and, lastly, six of these are doubled, and drawn out at a fifth head.

Thus it will be seen, that, by collecting all these numbers together, the doubling of the fibres of the cardings have been multiplied no less than 86,400 times; for $10 \times 10 \times 12 \times 12 \times 6 = 86{,}400$. The drawing is carried to this extent only in fine spinning. For coarse numbers, the doubling and drawing are not repeated so often. Six card-ends are usually passed through the first drawing-head, and formed into one riband. Six of these ribands are again formed into one; six of these again make a third sliver, and five of these pass through the last drawing-head. Thus we have $6 \times 6 \times 6 \times 5$, or 1080 of the original card-ends united in the finished drawn sliver.

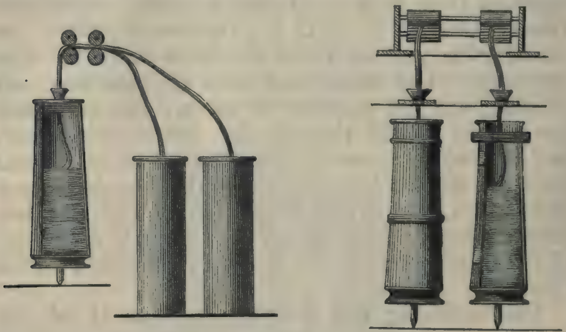
This doubling and drawing process is of the greatest importance, the quality of the yarn depending upon its being well done. Arkwright is the inventor of it; and it is related of him, that, when any defects appeared in his yarns, he told his people to look to their drawings, for, if they were right, every thing else would be so too.

The drawing-frames require constant watching, to

see that none of the cans are emptied before full ones are ready to supply their place.* The labour is performed by young women, who are kept pretty actively at work. A contrivance has been introduced which greatly abridges the labour. A cylindrical plunger is made to fall at intervals into the receiving-can, and, by pressing down the sliver, enables the can to hold a much greater quantity than it would do if the sliver were left to fall loosely into the can. Further improvements have lately been made, by which the sliver is regularly and beautifully coiled in the can, and compressed at the same time, but without at all stretching the sliver.

ROVING.

By the process of doubling and drawing, the cotton is formed into a loose porous cord, the fibres of which are arranged side by side. This cord is still much too thick for yarn, but it cannot be reduced in size

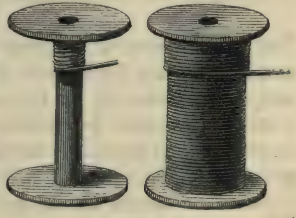


by drawing merely, for if this were attempted it would break; a slight twist is therefore given, which, by condensing the fibres, allows the drawing to pro-

* By a recent invention, in case of the breaking of any sliver, or the emptying of a can, so as to lessen the number of the slivers, the machine is made to stop instantly; thus requiring much less attention, and insuring a greater uniformity in the thread.

ceed. This is the commencement of the spinning process (which is, in fact, little more than a combination of drawing and twisting), and is called *roving*. Up to a recent period, the roving-machine, as introduced by Arkwright, was in use, but it is now superseded by better and more complicated mechanism. The roving-machine of Arkwright did not differ greatly from the drawing-frame. It consisted of two pairs of drawing-rollers, for extending the slivers, of which two were generally doubled and united. The sliver, as it quitted the drawing-rollers, was received into a can, which was made to spin rapidly round, and this, by giving a slight twist to the sliver, formed the roving, and distributed it in a coil within the can. Thus far all was well, but it was necessary for the next process that the roving should be wound upon bobbins; the can, when full, was therefore carried to a simple machine, and wound by hand, by which it was scarcely possible to avoid injuring the delicate cord, and hence the quality of the yarn suffered. This led to the introduction of the *Jack frame*, or *Jack-in-the-box*, as it was more familiarly called, and afterwards to the *bobbin-and-fly frame*, which may now be considered as the established roving-machine of the cotton manufacture.

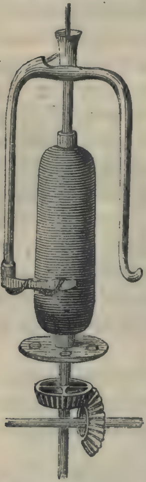
The bobbin-and-fly frame is an exceedingly complicated machine, although the objects to be accomplished by it are sufficiently simple; namely, to give the roving a slight twist, and then to wind it on the bobbin. The first is easily done by the revolutions of the spindle; the second is more difficult. It is scarcely necessary to explain, that the bobbins now under notice differ in no way



BOBBINS.

from the reels in common use, except in being of very

large size. The spindle, which holds the bobbin, is a round steel rod, driven by a small cog-wheel, fastened on the lower part of the spindle, as shown in the next figure. The bobbin is slid upon the spindle, and the small bed, or platform, on which it rests, is made to revolve by another series of small wheels, not shown in the figure. The spindle has two arms, called the *fly* or *flyer*. This fly is fixed on the top of the spindle in such a way, that it can be taken off in an instant, for the purpose of putting on or taking off the bobbin. One arm of the fly is hollow, the other



solid, and this serves to balance the machinery. One machine contains from thirty to a hundred and twenty spindles, which, for economy of space, are placed in two rows, each spindle in the back row standing opposite the space left between two spindles of the front row.

The action of the machine is this: The sliver having been drawn by the rollers, is twisted, by the rapid revolutions of the spindle, into a soft cord or roving: this enters a hole in the top of the spindle, and passes down the hollow arm of the fly; it is then twisted round a steel finger, which winds it on the bobbin with a certain pressure. This spring finger is a beautiful contrivance by Mr. Houldsworth. Before this invention, the rapid motions of the fly caused the roving to become improperly stretched by the centrifugal force, but this is now prevented by twisting the roving round the finger: by its pressing the soft roving on the bobbin, each bobbin is made to hold a much larger quantity.

All this seems to be sufficiently simple; but the difficulties begin to appear when it is considered, that the delivering finger must move up and down, so as

to wind the roving evenly over the bobbin, and that, as the bobbin increases in thickness, a difference in speed is necessary to prevent the roving from being improperly stretched or broken. The first object is attained by making the bobbin slide up and down on the spindle, and the second by causing the strap which drives the bobbin to act on a conical instead of a cylindrical drum; thus giving to the movement a varying instead of an equal degree of speed.

It will be seen, that the spindle and bobbin are driven by different movements. This is necessary, because, if they both moved at the same rate, the roving would be twisted merely, and not wound upon the bobbin; but, by making the bobbin revolve a little quicker than the spindle, the winding is accomplished. For example, if the bobbin revolves fifty times, while the spindle only revolves forty, forty turns of the bobbin will have nothing to do with winding; but there are ten turns of the bobbin above those of the fly, which will perform the winding. Hence, the forty turns of the spindle produce twist, while the fifty turns of the bobbin produce ten coils of the roving upon its barrel.

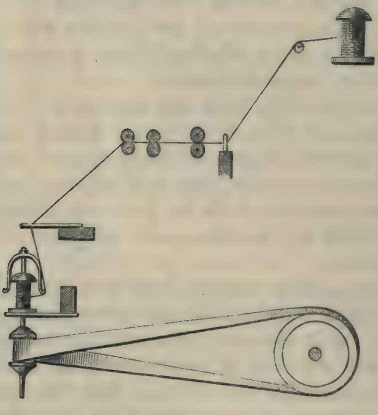
In fine spinning, two rovings are doubled and passed a second time through the frame, where they receive a further degree of drawing and twist.

The bobbin-and-fly frame is superintended by a female, whose duty it is to join the broken slivers, to remove the full bobbins, and to place empty ones in their stead.

In fine spinning, the rovings are sometimes prepared at what is called the *stretching-frame*, which is a kind of mule-jenny, to be noticed presently; but usually the rovings are finished at one of two machines, namely, the *throstle* and the *mule-jenny*. It may be stated, as a general rule, that the throstle spins warp, and the mule weft; there are, however, many exceptions to this.

THROSTLE SPINNING.

It has been already noticed, that Arkwright's water-frame was partially superseded by the mule-jenny, but that, as it was capable of producing a strong wiry thread, well adapted for warps, it was introduced in an improved form, under the name of the *throstle.* This machine is usually made double, a row of bobbins, spindles, &c. occupying each side of the frame. The bobbins, filled with rovings from the bobbin-and-fly-frame, are mounted at the upper part of the frame in two ranges. The roving from each bobbin passes through three pairs of drawing-rollers, where it is stretched out to the requisite fineness. On quitting the last pair of rollers, each thread is guided by a little ring, or a notch of smooth glass let into the frame, towards the spindles, which revolve with great rapidity, producing, by the motion of their flyers through the air, a low musical hum,



which is supposed to have given the name of *throstle* to this machine. The roving, which may now be called *yarn,* passing through an eyelet formed at the end of

one of the arms of the flyer, proceeds at once to the bobbin.

The yarn is wound upon the bobbin by a curious contrivance. The bobbin fits very loosely upon the spindle, and rests on its end upon a kind of platform. The bobbin is not connected with the spindle except by the thread of yarn which has to be wound; therefore, as soon as the flyer is set spinning, the thread drags the bobbin after it, and makes it follow the motion of the spindle and fly; but the weight of the bobbin, and its friction on the platform, which is promoted by covering the end with coarse cloth, causes it to hang back; and thus the double purpose is served of keeping the thread stretched and winding it on the bobbin much more slowly than the flyer revolves. The yarn is equally distributed on the bobbin by a slow up-and-down motion of the platform.

These effects are the same as were produced by the bobbin-and-fly frame, but in the throstle they are attained by simpler means. In the former machine, a distinct movement caused the bobbin to revolve quicker than the spindle. In the throstle, the bobbin is made to revolve by the pull of the yarn, which is now sufficiently strong for the purpose; but the roving in the bobbin-and-fly frame would not bear the strain.

A throstle-frame generally contains from 70 to 150 spindles on each side. The drawing-rollers extend the whole length of the frame. The top rollers are, as usual, covered with leather, and the thread passes over a guide bar, which has a slight horizontal movement, for the purpose of leading the thread over different points of the rollers, and thus preventing the leather from being chafed by constant pressure on one spot. One young woman, and an assistant, attend to from 140 to 300 spindles in two double frames; their duties are to mend broken threads, and shift the bobbins as required.

MULE SPINNING.

The throstle is not often employed for very fine spinning, because fine yarn would not bear the drag of the bobbin; but in mule spinning the yarn is wound at once upon the spindles without any strain. In the mule the roving is first drawn by the usual system of rollers, and then stretched by a moveable carriage, as in the spinning-jenny of Hargreaves. The effect of first drawing and then stretching, is to make the yarn finer and more uniform, as will be explained presently. The spinning-mule is the most interesting and impressive spectacle in a large cotton mill; on account of its vast extent, the great quantity of work performed by it, and the wonderful complication and ingenuity of its parts.

The spinning-mule consists of two principal portions; the first, which is fixed, contains the bobbins of rovings and the drawing-rollers; the second is a sort of carriage, moving upon an iron railroad, and capable of being drawn out to a distance of about five feet from the fixed frame. This carriage carries the spindles, the number of which is half that of the bobbins of rovings. Motion is given to the spindles by means of vertical drums, round which are passed slender cords, communicating with the spindles. There is one drum to every twenty-four spindles.

The carriage being run up to the point from which it starts in spinning, the spindles are near to the roller-beam: the rollers now begin to turn, and to give out yarn, which is immediately twisted by the revolution of the spindles; the carriage then moves away from the roller-beam, somewhat quicker than the threads are delivered, so that they receive a certain amount of stretching, a circumstance which gives value to this machine. The beneficial effect is produced in this way: when the thread leaves the rollers it is thicker in some parts than in others, and those

thicker parts not being so much twisted as the thinner ones, are softer, and yield to the stretching power of the mule, so that the twist is equalized throughout, and the yarn becomes more uniform. When the carriage has *completed a stretch*, or is drawn out from about 54 to 64 inches from the roller-beam, the drawing-rollers cease to give out yarn, but the spindles continue to whirl until the threads are properly twisted. In spinning the finer yarns, the carriage sometimes makes what is called a *second stretch*, during which the spindles are made to revolve much more rapidly than before. The drawing, stretching, and twisting of a length of thread being thus completed, the mule disengages itself from the parts of the machinery by which it has hitherto been driven, and the spinner then seizes the carriage with his left hand, and pushes it back to the roller-beam, turning at the same time with his right hand a fly wheel, which gives motion to the spindles. At the same time a *copping* wire, as it is called, is pressed upon the threads by the spinner's left hand, and they are thus made to traverse the whole length of the spindle, upon which they are then wound or *built* in a conical form, which is called a *cop*. These cops are used for placing in the shuttle in weaving, and form the weft, or short cross threads, of the cloth.

One man is able to attend to two mules, guiding in the carriage of one mule by hand, while the carriage of the other is being moved out by the steam-engine. Much skill is required in pushing back the carriage. As a preparatory step, the spinner causes the spindles to revolve backwards for a moment, to slacken the threads just completed, and throw them off the points of the spindles previous to winding them. In pushing the carriage back he must attend to three things:—he must guide the copping wire so as to insure the regular winding of the yarn on the cop; he must regulate the motion of the spindles; and he must push the carriage at such a

rate as to supply the exact amount of yarn that the spindles can take up in a given time.

The spinner is assisted by boys or girls, to piece the broken threads. He also employs a *scavenger* to collect all the loose or waste cotton, called *fly*, which lies on the floor, or hangs about the machinery. This is chiefly used in cleaning the machinery. It is calculated that the waste of material from the different machines in spinning cotton, amounts to $1\frac{1}{2}$oz. per lb. or nearly one-tenth of the original weight. It is the duty of the piecer to join the broken ends of the threads as the carriage moves from the upright frame. The breaking of the threads depends, in some degree, on the temperature and the state of the atmosphere. During an east wind the threads sometimes break faster than the piecers can join them; and it seems probable that the rapid whirling of so many thousand pieces of machinery produces, in very dry weather, a large amount of electricity, which may prevent the proper spinning of the fibres. At such times it is not uncommon to keep the atmosphere of the room moist, by jets of steam, and to maintain a temperature of from 68_{o} to 76^{o}. Indeed, fine yarn cannot well be spun at a lower temperature.

The quality of the yarn in mule-spinning depends upon the care and attention of the spinner, and it was long thought impossible to substitute mechanical contrivances for the work performed by him. This has led the spinners, on many occasions, to league together, for the purpose of compelling their masters to grant such wages as they chose to demand, and to accept such an amount of labour as they chose to give. Such acts as these, which are in direct violation of the Divine command, "Servants, be obedient to your masters," are sure, sooner or later, to meet with punishment; and such has been the case in the present instance. The mill-owners, feeling that no dependence was to be placed on their spinners, long

desired to supersede them by mechanical contrivance; and this at length, after numerous failures, has been done in a complete manner by the invention of the *self-acting mule*, or the *iron man*, as it is sometimes called in Lancashire. Mr. Roberts, of the celebrated firm of Sharp and Roberts, machine-makers, succeeded in perfecting this extraordinary machine, which not only does the work of the spinning-mule without the assistance or attendance of any one except the little piecer, but does it in a more perfect and complete manner; and produces a larger quantity of yarn. The cops, also, are firmer, and of better shape, and contain a much larger quantity of yarn than cops of equal size wound by hand, so that they are less liable to injury; and in weaving, the superior firmness of the cop allows the loom to be worked at greater speed, whereby cloth of superior quality is produced in greater quantity.

REELING.

The yarn is now disposed of in various ways, according to the use for which it is intended: but it is often found convenient to make it up into hanks.

The machine for winding the yarn from the bobbins, or cops, into regular hanks, is a long eight-sided frame, mounted on a carriage, which is also furnished with spindles or skewers, for holding the bobbins, or cops. These frames are managed by young women, whose duty it is to turn the reel until a check is struck. They then know that the reel has made eighty turns; and, as the sides of the reel measure one yard and a half, a *ley* or *rap* is thus formed, containing 120 yards. Seven of these raps make one hank, containing 560 threads of a yard-and-a-half each; thus making 840 yards to the hank. The size of the yarn is ascertained by weighing the hanks in

a kind of balance called a quadrant.* Each size is put up separately in cubical bundles of five or ten pounds weight. These packages are closely com-

REELING.

pressed by a simple but ingenious machine called the *bundling-press,* where they are firmly tied while under pressure, and, being wrapped neatly in paper, are ready for the market. The usual average number of hanks to the pound is, for coarse spinning, from ten to forty, but, for some purposes, such as candle-wicks, coarse counterpanes, &c., as low as two hanks to the pound are made. It is often exported as low as from four to six hanks. The highest number usually obtained in fine spinning is 300, but the writer saw at Mr. Houldsworth's mill, at Manchester, yarn of which 460 hanks were required to make a pound. This yarn is a beautiful, hard, cylindrical cord, of wonderful fineness, and has been sold for *twenty guineas,* or upwards, a pound, an astonishing example of the effect

* Tables are published for ascertaining the number of hanks to the pound; but the following is not an uncommon mode of ascertaining. 1,000 grains divided by the number of grains in a ley, gives the number of hanks per pound. This rule is founded on the fact that a ley is $\frac{1}{7}$th of a hank; and 1,000 grains is equal to $\frac{1}{7}$th of a pound.

of well-directed industry, in increasing the value of raw material. A pound of the best sea-island cotton is worth, at the highest price, 5*s.* per pound; when manufactured into yarn of the number 460, the value of this pound of cotton is 420*s.*, or, in other words, its value is increased 84 times. This yarn was produced by Mr. Houldsworth for a muslin dress for Her present Majesty, in order to show the capabilities of the British manufacture, far excelling any thing produced by the Hindoo spinner. It is scarcely necessary to say, that such yarn is not commonly made, but that, if a demand for it were to arise, it could be supplied at a gradually decreasing price.

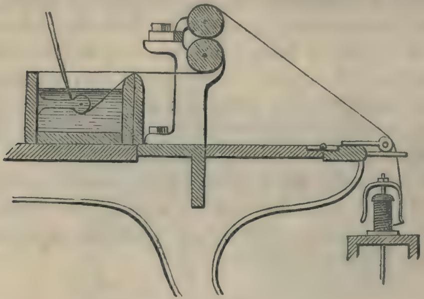
THE MANUFACTURE OF SEWING THREAD.

WHEN the yarn is completed, it is usually sent to the *doubling and twisting mill*, for the purpose of being converted into what is now properly called thread. Although we are accustomed to apply the word *thread* to a thin, narrow line of any fibrous material, the manufacturer limits the term to that compound cord produced by doubling or twisting two or more single lines. The single line he calls *yarn:* two or more single yarns laid parallel, and twisted together, he calls *thread;* and of this there are many varieties, such as *bobbin-net-lace thread, stocking thread, sewing thread,* &c.

The writer visited a sewing-thread factory at Manchester, which, though inferior in extent and importance to the cotton mills, where the raw material is converted into yarn, presents, nevertheless, several points of interest.

The yarn, which is received at the factory in the form of cops, is wound upon large bobbins, ready for the doubling-mill, or *thread-frame,* as it is sometimes called. This machine is not unlike the throstle of the cotton-spinner, already described; but its

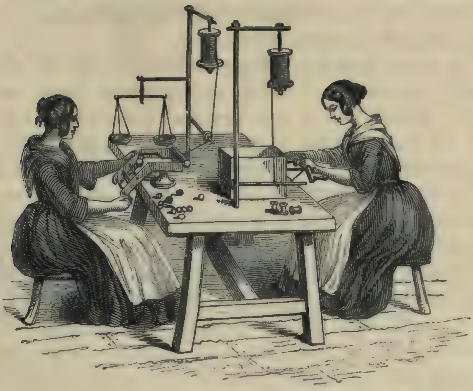
action will be better understood by reference to the following cut. The cops are mounted loosely upon



spindles or skewers, on a *creel* or shelf extending the whole length of the room; as the yarn is unwound, it is led across a glass rod, and made to pass into a leaden trough filled with water, or a weak solution of starch, which enables the lines of yarn to twist together into a more solid thread. On quitting the trough, the lines of yarn (two, three, four, or six in number, according to the desired size of the thread) are guided over a roller whereon they are laid parallel, and then made to pass down to the spindle, the rapid revolutions of which twist these parallel lines together into a solid cord or thread. The twist is given in an opposite direction to that applied by the spinning-machine, and when the thread is completed, it is then wound upon the bobbin which surrounds the spindle.

The thread is now wound into hanks for bleaching or dyeing (two important processes, which will be noticed in a separate treatise). The hanks of bleached or dyed thread are wound on bobbins, for the purpose of *balling* or *reeling*. The process of forming the thread into balls or reels, is performed by young women with an almost magical celerity. Each young woman is seated at a kind of turning-lathe; she

seizes the end of the thread, and attaches it to a rod of steel, sets this spinning, and in an instant a ball of cotton appears at the end of the rod; the rotation



BALLING AND REELING.

is stopped, a blue ticket is inserted at the end, a further quantity of thread wound to secure the ticket, and the ball is finished. The size of the ball is regulated with extreme accuracy by the eye. The number of balls to the pound varies from 16 to 600; and the young woman being told to produce a certain number to the pound, makes a few, weighs them until she has got the exact size by weight; after this she relies entirely upon her eye, and so accurate is her judgment, that the variation of the balls in weight is very trifling. The cotton is wound on reels with the same surprising celerity; the steel finger which delivers the thread from the bobbin, being guided to and fro to distribute it equally along the barrel of the reel. The quantity here also is judged of by eye, and varies from 30 to 300 yards in each reel. As each reel is filled, the broken end of the thread is inserted in a notch, which the

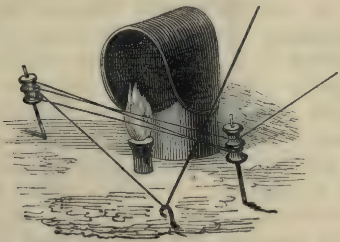
winder cuts for the purpose. Reeling is not such rapid work as balling, but is still sufficiently swift to prevent the eye from following the motion of the thread. The chief delay in both cases arises from the breaking of the thread, which, during the writer's visit, occurred rather often.

The reels are placed on end in a kind of shallow drawer, and little children cut out and paste on the labels. These labels are printed on sheets, and the back of each sheet is covered with gum, like the postage-stamps. The children stamp out the labels with a circular punch, wet the back of each against the tongue, and then press the wetted side against the end of the reel. Some idea may be formed of the extent of this business, from the fact, that a sheet, containing 144 labels, printed in blue and gold, and glazed, and then covered on the back with a layer of gum, is sold for one penny. The smallest bronzed cotton bobbin labels are sold as low as one halfpenny per gross. The writer paid a visit to the extensive establishment of Messrs. Bradshaw and Blacklock, of Manchester, where these labels are produced in large quantities. Each sheet, which is of a purple colour on one side, and plain on the other, is first printed from a copper-plate in an invisible adhesive ink; the sheet, immediately it is printed, is taken by a boy, who rubs over it, with a hare's foot, a yellow impalpable metallic powder, which passes for gold, but is really copper or bronze in a minutely divided state. The powder adheres to the printed letters and border, and is brushed off from the parts where no ink has been applied. The sheets, when perfectly dry, are hot-pressed, or calendered, which gives the glossy surface, and then covered on the plain surface with gum; when this is thoroughly dry, the sheets are pressed again, and are then ready for sale. Letter-press and copper-plate printing, as well as lithography, are all extensively used in producing labels and tickets.

The balls of cotton are tied up in small flat bundles, each containing a quarter of a pound; the proper number is counted out, folded up in paper, and tied into a bundle, with the remarkable speed and precision which is attained only by long practice: four of these quarters are next tied up into pound parcels, which, after being labelled, are ready for the wholesale market.

SINGEING THE THREAD.

In fine spinning, the yarn, when doubled, is, for some purposes, *singed* or *gassed*, in order to get rid of the loose fibres, and to make it more level and compact. The process of singeing yarn strikes a stranger as being more remarkable than anything else in the mill. In a long room in the upper part of the mill, or in a shed attached to it, are several tables, lighted up with a large number of jets of flame, about twelve inches apart, producing a singular but pleasing effect. Above each flame is a little hood or chimney. On entering



GASSING THE YARN.

this room the smell of the burnt cotton is immediately perceived, and, on approaching the table, one is surprised to see a fine, delicate thread crossing each

flame in two or three directions, and apparently at rest; but, on following the course of this thread, it is found to proceed from one bobbin, which is rapidly spinning round, and to pass through the flame to another bobbin, which is also in rapid motion. It is then seen that the thread is also moving at a rapid rate, by which means alone does it escape being consumed. The thread is led over pulleys, so as to pass two or three times through the flame, which singes off the loose fibres, converting them into a reddish powder or dust, which, if blown about and inhaled, would do great injury to the lungs: this is why the gassing-room is in a remote or retired part of the building, to prevent the air being disturbed by the bustle of the busier parts.

After the thread has been singed, it passes over a brush, to clean it, and then through a small hole or notch cut in a projecting piece of brass, which is ingeniously made to detect any knot or foul point in the thread. The hole is so small, that there is but just room for the thread to pass; if, therefore, a knot or other impediment occurs in the thread, the piece of brass is depressed, and this is connected with mechanism which suddenly turns the gas flame aside, and lifts the bobbin off the rotating barrel which turns it, causing the whole to stop. The thread remains at rest until the attendant, called the *tenter-woman*, mends the defect, and sets the bobbin in motion again. The advantage of this contrivance is, that no time is lost; for, while the defective thread stops, all the rest go on as usual. The effect of singeing is to raise the yarns to a higher number, by the diminution of their weight per hank. Thus, No. 90 will become No. 95; so that there is an actual difference of five hanks per pound by the operation of gassing.

STATISTICS.

The statistics of the cotton trade will be better understood, when the important subjects of weaving, bleaching, dyeing, and printing, are completed; but a few details respecting cotton-wool, yarn and thread, may be interesting in this place. The amount of cotton-wool imported into England in 1845, amounted to 659,584,477 lbs., of which, 44,363,355 lbs. were exported, leaving a quantity for home consumption, amounting to 615,221,122 lbs. By far the greater part of this supply came from the United States of America. For some years past, the cotton-wool imported from foreign possessions paid an import duty of 2*s.* 11*d.* per cwt.; that from British possessions paid only 4*d.* per cwt. From the 22d of March 1845, this duty was wholly repealed.

In 1845, the prices of cotton-wool at Liverpool, were as follows:—Sea Islands cotton-wool from $10\frac{1}{2}d.$ to 16*d.* per lb.; Uplands, $5\frac{3}{8}d.$ to $4\frac{1}{2}d.$; Orleans, $5\frac{1}{4}d.$ to 6*d.*; Egyptian, $5\frac{1}{2}d.$ to 10*d.*; common West Indian, 4*d.* to 5*d.*; Surat and Madras, $2\frac{1}{2}d.$ to $3\frac{3}{8}d.$

The quantity of cotton-yarn spun in England and Scotland in 1845, was as follows:—

	lbs.
In England	467,029,465
In Scotland	27,737,022
Total	494,766,487

The quantity of cotton-yarn exported from England in 1845, amounted to 131,937,935 lbs. Of this quantity, the principal portions were distributed as follows:—

	lbs.
The Hanse Towns, &c.	40,315,592
Holland	21,556,043
Russia	18,167,962
India	14,116,237
China	2,402,750
Sardinia, Tuscany, &c.	4,482,539
Belgium	3,917,267

The remainder was sent in much smaller quantities to various parts of the world.

The quantity of cotton-thread exported in 1845, amounted to 2,567,705 lbs.

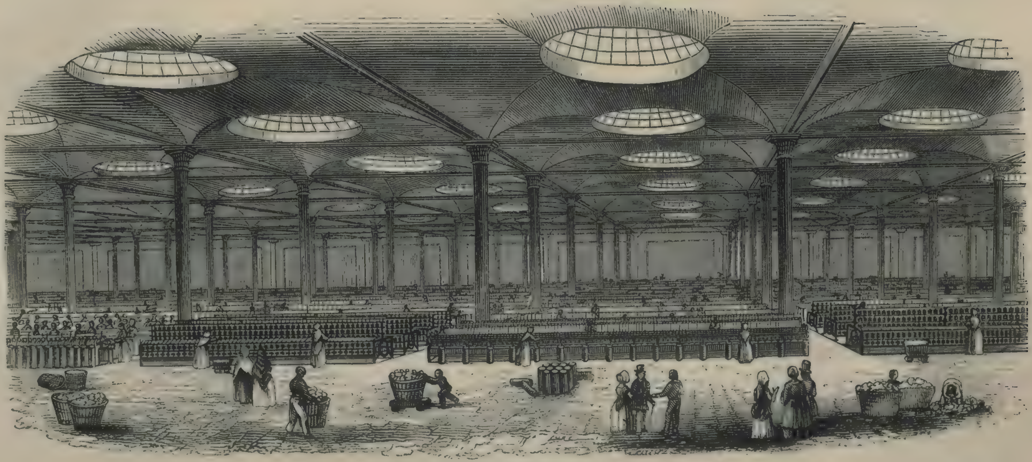
The total weight of yarn in manufactured cotton-goods exported from England in 1845, amounted to 336,866,327 lbs.; the total value of which was £22,063,898.*

Much has been said respecting the health of the operatives in cotton-mills. Children under thirteen years of age are now under the protection of the legislature; they are allowed to work only half time, that is, six hours a day; and they must attend school during some portion of the day. An excellent school, frequently under the inspection of the Committee of Council on Education, is attached to a large number of factories; and unless the children attend this every day, they are not allowed to work in the mill. It is generally arranged that those children who work during the morning attend school in the afternoon, while those that work in the afternoon go to school in the morning.

The writer was agreeably disappointed to find that the work-people in the mills had by no means that sickly appearance which he had been led to expect. On the contrary, many of the younger females were stout, healthy looking girls, and others, though not ruddy, were lively and active in their movements, and in their expression of countenance. There were no symptoms of suffering or disease among the young people in any of the mills visited by the writer. Perhaps the most trying operations in the cotton-mill are *willowing*, *batting*, and *carding*. The rooms in which they are carried on are clouded with fine particles of cotton, which sometimes set a stranger coughing immediately on entering; this is probably injurious to the work-people. Most of the men

* The above statistical facts are stated on the authority of *Burn's Commercial Glance*. Manchester, 1846.

in these rooms were pallid in their complexions, and, though from habit they are not subject to the same inconvenience and difficulty of breathing which strangers suffer, there are evident marks of a languid state of health in the countenances of some. In judging from their appearance, however, it is necessary to make due allowance for an artificial whiteness, produced by the particles of cotton, which settle abundantly on their faces and hair.



INTERIOR OF MARSHALLS' ONE-STORIED FLAX-MILL AT LEEDS.

THE

MANUFACTURE OF LINEN YARN.

The art of preparing the fibres of flax and weaving them into linen cloth had reached a high degree of perfection among the Egyptians, so early as the time of Joseph; for we read, (Gen. xli. 42,) that Pharaoh arrayed Joseph in vestures of fine linen. Two centuries later the Hebrews were evidently acquainted with the arts of spinning, weaving, dyeing and embroidery; for when Moses constructed the tabernacle in the wilderness, it is related (Exod. xxxv. 25, 26,) that "all the women that were wise-hearted did spin with their hands, and brought that which they had spun, both of blue, and of purple, and of scarlet, and of fine linen. And all the women whose heart stirred them up in wisdom spun goat's hair;" and again, verse 35, "Them hath he filled with wisdom of heart, to work all manner of work, of the engraver, and of the cunning workman, and of the embroiderer, in blue, and in purple, in scarlet, and in fine linen, and of the weaver, even of them that do any work, and of those that devise cunning work." These passages contain the earliest mention of woven clothing, and the arts therein enumerated were probably acquired by the Israelites during their captivity in Egypt, where linen was the national manufacture. That the ancient Egyptians were

unacquainted with cotton, seems evident from the fact, that among the innumerable specimens of mummy-cloth which have been imported into Europe, not a single particle of cotton has been found, and there are no paintings of the cotton shrub upon the tombs of Thebes, where accurate representations of flax occur in its different states of growth and manufacture. Egypt exported linen yarn and fine linens to the kingdom of Israel in the days of Solomon, (see 2 Chron. i. 16; Prov. vii. 16; and also Ezek. xxvii. 7,) and to Greece in the days of Herodotus. The Egyptians were also noted for their manufacture of linen and their exports of flax under the Roman emperors.

Linen was worn by all nations west of the Indies, while in India the practice of converting flax into linen seems never to have been introduced. This may be accounted for by the fact, that India possessed the cotton plant, the wool of which can be converted into yarn so much more easily than flax, and the clothing prepared from it is so admirably adapted to the climate. Flax is cultivated in India only on account of its seed; but the plant, which is most valued in other countries, is there thrown away.

HISTORY AND CULTIVATION OF FLAX.

Common flax *(Linum usitatissimum)* is the most useful and important species in a genus of plants called *linum*, from the Celtic word *llin*, a thread. It is an annual plant, sending up slender, smooth, upright stems, about the thickness of a crow-quill. The stems are hollow pipes, and the fibre which surrounds them is the material used in making linen goods of every description. The plant rises two or three feet high, with long narrow leaves of a greyish colour, placed alternately on the stems; at the top

the stems branch into slender footstalks, each terminating in a pale blue flower, of five delicate petals. The blossoms open in July, and are succeeded by large globular seed-vessels, each containing ten seeds. This is the well known *linseed*, the oil of which is so much used in the arts, while the refuse husk, after the seeds have been crushed for oil, forms the linseed cake, or oil-cake, on which cattle are fattened. The flax plant, thus extensively useful to man, is also ornamental when planted in flower gardens, though some of the dwarf species are perhaps still better adapted for this purpose.

THE FLAX PLANT.

The cultivation of this plant is carried on in widely distant countries; for its valuable properties are known and appreciated in every civilized community, and it is so easily raised that there is much inducement to cultivate it. The principal countries whence we obtain flax, are Russia, the Netherlands, Prussia, and France, with small quantities from America, Italy, and New South Wales. The soil best adapted to its growth is a deep rich loam, mellow and loose to a considerable depth, and containing much vegetable matter. Hot gravelly soils, or cold wet clays, would be fatal to it; but any other description of land may be so cultivated as to be fit for flax. The cultivation of this crop was formerly pretty general throughout this country, and it still forms an important part of the agriculture of Ireland. The reason of its decline in England was doubtless its being found much less profitable than the culti-

vation of corn, while it was also considered very impoverishing to the soils. The latter idea seems to have been erroneous. Under an improved system of cultivation, the refuse of the flax, and the water in which it has been steeped, are returned to the soil as manure, while the linseed cake is used for fattening cattle on the farm. Thus, what is lost in one way, is restored in the other. After flax-growing, it is, however, necessary to allow an interval of six or seven years, before the land is ready to receive the same crop again. In the best soils of Flanders flax is grown in the third year of a seven-course rotation, or the fifth year of a ten-course rotation.

In that country, where the greatest care is bestowed upon the growth of flax, the preparatory crops are barley or rye, with turnips after them the same year. All these crops are highly manured, and before the flax-seed is sown, peat ashes, at the rate of thirty bushels per acre, are spread and harrowed in; the land is also dressed with liquid manure, which is left for a week or ten days to soak thoroughly into the soil. The seed is then sown very abundantly, in the general proportion of 160 lbs. to the acre. It is lightly covered in by a bush-harrow drawn over the land, for if the seed were buried more than half an inch deep it would not vegetate. In the flax-growing districts of Ireland, this crop frequently follows potatoes; but this is considered injurious to the fibre, rendering it coarse and the stalks uneven, from the manure not being perfectly incorporated with the soil.

In the southern climates flax is sown before winter, and pulled in the spring; but in our own and other northern climates it is sown in March or April, and pulled in summer. Repeated ploughings and harrowings fit the soil for its reception, and it is then sown in a similar manner to corn—the seeds being equally distributed over the surface. A slight harrowing, and the passing of a roller over the ground

ensures quick and even germination. If the quality of the fibre be a chief object with the cultivator, he sows the seed very thickly; the plants, in consequence, come up in a crowded manner, and are tall and of delicate growth, the fibres being delicate in a corresponding degree. If the seed be the chief object, thin sowing is best: the stalks then become strong and coarse in fibre, and much branched at the top, thus producing an increased quantity of seed. In sowing flax, it is customary to use seed obtained from Riga and other foreign countries, as that of home-growth is found inferior in quality after the third or fourth year. Clovers and grasses are occasionally sown with flax, but this is not done without injury to the flax crop.

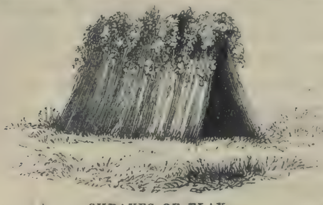
When the plants are a few inches high, weeding commences. In Flanders this is performed by women and children, who with coarse cloths around their knees, creep along on all-fours, which injures the young plants less than walking on them. The weeders also take care, if possible, to face the wind, that the tender flax, bent down by their weight, may be assisted by the wind in rising again. When weeding is too long delayed the plants are bruised and injured, and cannot recover their erect position.

In thickly sown flax the plants are liable, if unsupported, to be laid by the wind, and consequently spoiled. This is especially the case with the taller varieties. There is a very fine long variety, cultivated in the neighbourhood of Courtray in Flanders, which without support would be laid flat by the least wind. To prevent this, short stakes are driven into the ground, in a line at eight or ten feet from each other, and long slender rods are tied to them with oziers, about a foot or eighteen inches from the ground, forming a slight railing to support the flax: a number of these are placed at a short distance from each other in parallel lines all over the field, and the flax is thus prevented from being beaten down. A more

simple plan is pursued by some cultivators. Stakes are driven into the ground at regular intervals, and small ropes tied to them instead of rods. The ropes are carried lengthways and crossways, and thus form a sort of net work over the whole field.

METHOD OF SUPPORTING FLAX.

The time of pulling the crop depends upon the season, and upon the intentions of the grower. If fine fibre be his object, he pulls the flax rather green; but if the quality of the seed be considered, a longer time is given before pulling. The latter object is generally attained when two-thirds of the stalk have turned yellow, and when, by cutting the seed-pods across with a knife, the seeds have changed from their fluid state, for they ripen sufficiently after the flax is pulled, if not separated from the stalk. Taking up the crop in a wet state is avoided if possible. The pulling is carefully done by small handfuls at a time, which are laid regularly two and two across each other to dry, and are soon afterwards collected in larger bundles, the root ends on the ground, and the seed-ends slightly tied together, as sheaves of grain in the harvest field. The practice of cultivators differs very much as to the after processes. Some disregard the seed altogether, and commence steeping the flax at once. Some carry the flax as soon as it is dry under a shed, and take off the capsules containing the seed, by a process called *rippling*. Others house the flax as soon as it is



SHEAVES OF FLAX.

dry, allowing the seed to remain on, and deferring the process of rippling and steeping until the following season.

RIPPLING.

RIPPLING is sometimes done in the field, in which case a large winnow-cloth is spread, and the ripple placed in the centre of it. This is an instrument like a comb, with smooth round teeth of iron, standing about twelve inches out of the wood, and placed so close together that the pods cannot pass through. The ripple is screwed down to a long stool, and two men seated at the ends alternately draw their handful of flax through the teeth of the comb. This sepa-

RIPPLING.

rates the bolls or seed-heads from the stalks. If the rippling is performed the same day the flax is pulled, the second day it is taken to be steeped; and the ponds are of a size sufficient to contain one day's pulling and rippling. The system pursued with the Courtray flax is different from this, and is strongly recommended to cultivators in this country. The flax being set up in well-formed stooks, is dry in eight or ten days, when it is made up into what are called small wind-stooks in the field, and is finally carried to the barn, or stacked in some convenient situation. The seed is taken off in the leisure time

during winter, not by rippling, but by threshing with a stick, the foot being kept on the root end of the flax to prevent its turning about. The steeping takes place in the following May and June, and the superiority of the samples thus treated, affords proof that the idea commonly entertained—that keeping the flax injures the fibre—is an erroneous one.

STEEPING THE FLAX.

Steeping or *Retting* the flax is a very important process, by which the fibrous bark is separated from the woody portion of the stem. A certain degree of fermentation is excited by the process, but this must be carefully watched and stopped at the right time, otherwise the colour of the flax will be destroyed and the quality injured. In this country it is usual to steep the flax in ponds, but the steepers of Courtray (where steeping is a distinct trade) prefer running water. For this purpose they make large frames of oak-rails, fill them with bundles of flax, and sink them by weighted boards just below the surface of the river Lys. There are posts driven into the river, to prevent the frames being carried away by the stream, and each steeper has a certain portion of the bank, which is a valuable property. The flax takes a longer time in steeping in this way, than in stagnant water, it also loses somewhat in weight; but the colour is so much finer, that flax is sent to be steeped in the river Lys, from every part of Flanders.

According to Phillips, there is an Act of Parliament still in force in this country, by which the retting of flax in rivers or any waters where cattle are accustomed to drink is forbidden; as such water is found to communicate a poison, destructive to the cattle which drink it, and to the fish which live in it. Flax sends out a disagreeable odour while steeping in ponds, which is said frequently to cause fever in

the neighbourhood where it is carried on to a great extent.

The steeping of flax in ponds (called *water retting*) is well described in Sproule's Essay on the Growth and Management of Flax in Ireland, which obtained the gold medal of the Royal Dublin Society. He says, "The water for the purpose should be soft, to ensure which it is well that it should be collected in the pond for some time previous to the flax being steeped. It is also of importance, that the water should not be changed during the time the flax is in it, the quantity required from leakage being however cautiously supplied. Above all, it is necessary to guard against the use of water impregnated with any mineral substance, which would prove destructive to the flax. In order to guard against this, therefore, it may be necessary to form a cut all round the flax pond, which may be filled up with stones, by which the ingress of injurious matters will probably be prevented. The selection of proper situations for these ponds is too little attended to in this country; although the treatment in watering, exercises a powerful influence on the quality of the flax. The ponds should at least be of sufficient depth to admit of the flax being placed almost upright in them, and the length and breadth may be determined by the locality, or the quantity of flax to be steeped. The flax is put into the pond with the root end undermost, and a covering of straw or other matters, to shade off the light is found to be advantageous. When covered over in this manner, stones are afterwards to be placed along the surface, to prevent any portion of the flax from rising above water. Although any considerable current through the pond is not desirable, yet such a flow as will carry away the impurities caused by the fermentation, is essentially necessary to produce flax of a good colour."

When the flax has been long enough in the water, it will begin to sink in the pond, and the fibres will

readily separate from the stalks by rubbing. In warm weather eight or ten days will sometimes effect this, in other cases ten or twelve, the precise time not being subject to rule. The flax is next taken out of the pond, and placed on the banks to drain for a few hours, after which it is spread out evenly on short close pasture land, the rows being laid perfectly straight to prevent confusion in turning.

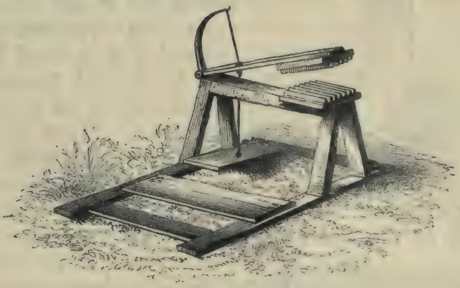
The Belgians spread their flax much thicker than it is done in Ireland, which prevents the weather from hardening it too much before it is properly bleached, and also renders it much less easily tossed about by winds. While flax is thus spread out upon the ground, it receives three or four turnings, and this is done by means of long poles or wattles, run under the rows, beginning with the first row, and proceeding so that the second falls upon the ground previously occupied by the first. Those accustomed to this work, can perform it so well, that the flax after three or four turnings appears as even and regular in the rows as at first. Much more attention is paid to this process on the continent than among ourselves; and this is another reason why uniformity of colour is so much greater in foreign than in native flax.

The separation of the bark from the fibre is sometimes effected by *dew-retting*, that is, exposing the flax to the influence of dews and rain, instead of steeping it in a pond. This is of course a much slower process than the former. What is called *mixed retting* is perhaps the best, the flax being in this case macerated in water, and the retting is finished in the air.

BREAKING.

When the flax is thoroughly dry, it is again bound in bundles, and is either put up in small stacks, loosely built, where it improves by keeping; or it is at once subjected to the processes necessary to prepare

it for the manufacturer. These are, first, bruising the woody parts of the stem. This was formerly done with a hand-mallet, which is still in use in several parts of the north of Ireland, but the operation is much better performed by machinery. The common brake consists of four wooden swords fixed in a frame, and another frame with three swords, which play in the interstices of the first, by means of a joint at one end. The flax is taken in the left hand, and placed between the two frames, and the upper frame is pushed down briskly upon it. It breaks the flax in four places, and by moving the left hand, and rapidly repeating the strokes with the right, the whole handful is soon broken. A variation of this contrivance sometimes



THE BRAKE.

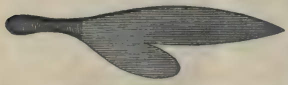
employed, consists of two wooden frames attached to each other by a hinge, the cross bars of which are so placed, that two of them shall not be opposite each other, the upper frame having a bar less than the lower one. The parts acting on the flax are of iron, and are worked by a simple contrivance, which enables the workman to keep the frame in motion with his left foot. Between these frames the flax is beaten and bruised until ready for the scutcher. But a still better mode of preparation is by subjecting the flax to the action of rollers placed close together, and revolving in contrary directions, similar to those of a

thrashing machine. The action of these can be regulated according to the quality of the flax.

SCUTCHING.

Scutching is the next operation, and is performed either by machinery or manual labour. The latter is almost universal on the continent, and is most carefully performed. But where flax is extensively cultivated in this country, the difficulty of procuring hands for the work makes machinery necessary. Scutching by hand is performed by means of a board set upright in a block of wood, and having a horizontal slit about three feet from the ground. The bruised flax is held in the left hand, and inserted in the slit so as to project to the right. Here it is repeatedly struck with a flat sword or scutcher, the blows being directed close to the slit, through which the flax is at the same time drawn by degrees, so that every part of the stem receives a blow sufficient to beat out the pieces of wood adhering to the fibre, and to leave the latter loose and free for heckling. In flax mills, the operation of breaking is performed by passing the stems between three fluted cylinders, one of which is made to revolve by horse or water power, and carries the other two round. That of scutching is accomplished in the same mill, by means of four arms projecting from a horizontal axle, so as to strike the stalk, or *boon*, as it is technically called, in a slanting direction, until the useless parts are beaten away. The operation of these mills has been much objected to, on the ground that

SCUTCHING FRAME.



THE SCUTCHER.

they mutilate and destroy the fibre in a great degree before the woody part is separated; and in consequence, a premium of one hundred guineas has been offered by the Flax Improvement Society of Ireland for the machinery best adapted for the purpose. Several clever inventions have been the result; but none perfectly answering the object in view. The Committee of the same Society have lately published general directions for the management of the flax crop; among which are the following useful hints for avoiding the exhaustion of the land. "If the seed be saved, and the cattle fed upon the bolls, a valuable addition will be made to the manure heap, as, perhaps, the richest manure is produced by this kind of food. The putrescent water from the flax-pools should be carefully preserved, and either used as a top-dressing for grass, or mixed with the weeds and other refuse of the crop, to ferment. By these means, almost all the matter abstracted from the soil by the flax crop, would be returned in the shape of manure, the fibre being supplied by the atmosphere alone."

The flax of New Zealand *(phormium tenax,)* is said to exceed every other species in strength of fibre and whiteness; qualities which, if it really possess in the degree stated, must make it peculiarly well fitted for being made into canvass and cordage.

DIVIDING THE FLAX INTO LENGTHS.

THE flax being freed from all its woody particles is ready for the flax mill, where it is converted into linen yarn. In describing the interesting processes of this manufacture, the writer has to express his acknowledgments to Messrs. Marshall and Co., of Leeds, who kindly permitted an inspection of their extensive mills, and also allowed drawings to be made of the principal machinery.

The flax is conveyed from the wagons in the street, by a lifting apparatus, to the upper floor of a five-

storied building, where it is opened and prepared for spinning.

The length of the flax varies from twenty-six to thirty, or thirty-six inches. The part nearest the root is coarse and strong, the middle part fine and strong, and the upper part still finer, but not so strong. The flax is therefore divided into three lengths, and the parts from the bottom, middle, and

DIVIDING THE FLAX INTO LENGTHS.

top being collected into separate heaps or *stricks*, as they are called, several qualities of thread are afterwards formed from them. Sometimes, however, the whole length of the flax is divided into four or five parts, which are called *middles*, *ends*, and *middle* and *end middles*.

In this division of the flax, it is necessary for the after process of spinning, that the ends of all the separate parts should be rough or ragged, such as would be produced by breaking or tearing a thread or filament instead of cutting it. For this purpose an ingenious machine is used, consisting of a number of upright wheels, and a centre wheel furnished with oval teeth. The boy holding a bundle or handful of

flax at both ends, passes it between two wheels on either side of the upright wheel, which hold it securely while the centre wheel tears it across. The centre wheel moves with very great speed, while the outer, or holding wheels, move slowly; so that the dividing wheel has time to perform its work before the flax escapes from the pressure of the holding wheels. The bottom part is first separated from the middle, and the middle from the top, and the three are formed into separate heaps or stricks.

HECKLING.

The next process is *heckling*, an operation by which the filaments of flax are cleaned, split, separated into their finest fibrils, and arranged in parallel order; and the short fibres which are unfit for spinning, together with any dust or dirt, are, at the same time, completely removed. The *heckle* or *hackle* is a sort of comb, resembling the *hand*, or rather the *stock cards*, formerly used in carding cotton and wool. The teeth of the heckle are usually of iron or steel, from one to two inches in length; their points are very sharp and smooth, and are all arranged at equal distances from each other, and at an equal level, for which purpose they are passed through holes in a brass or iron plate, which is firmly fixed to a square or circular block of wood, rising from an oblong plank. Two or more heckles, of different degrees of fineness, may be mounted side by side on one plank; the teeth may be arranged in a circle, or in parallel rows. The coarse heckle is furnished with teeth about one-tenth of an inch thick, and one inch and a quarter long, tapering from the middle into a very fine point. A fine heckle may contain upwards of a thousand teeth. It is said, that if the points of the teeth are four-sided, instead of round, the edges are useful in separating the fibres.

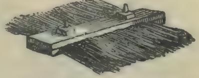
In carding cotton or wool, the filaments are

arranged in proper parallel order, by placing the lock between two cards, which are moved in opposite directions. In performing a similar operation with flax, only one card or heckle is used at a time. The workman with one hand seizes a strick or lock of flax by the middle, throws it upon the points of the coarse heckle, and draws it towards him; at the same time, with the other hand spreading the flax, and preventing it from sinking too deeply among the teeth. By this operation the flax is divided into two parts; namely, the short fibres, forming *tow*, which remains between the points of the heckle, and is from time to time removed; and the long fibres, called *line*, which remains in the hand of the heckler. One half of the length of the strick being properly heckled, the other half is turned round and prepared in a similar way. The process is then repeated upon the fine heckle, and continued until the required fibre is produced. It is calculated that one hundred pounds of well cleaned flax, will yield from forty-five to sixty pounds of line; the remainder consisting of tow, boony particles, and dust. Considerable force and dexterity are required to heckle well, for in the hands of an unskilful operative, the best flax, instead of being separated into fine delicate parallel lines, will nearly all be converted into tow, (which is much less valuable than line;) but a good heckler throws the flax more or less deep among the teeth, according to circumstances, feeling the amount of resistance required, and drawing it with the proper degree of force and velocity.

To assist the heckler in splitting the filaments, the flax is sometimes, between the first and second heckling, folded up into a bundle, and beaten upon a block with a wooden mallet, after which it is well rubbed with the hands. A similar object is gained by bruising it upon a smooth board with a stiff brush, and also by boiling it in potash lye.

Machines have been contrived for the purpose of superseding heckling by hand, and in all of them the

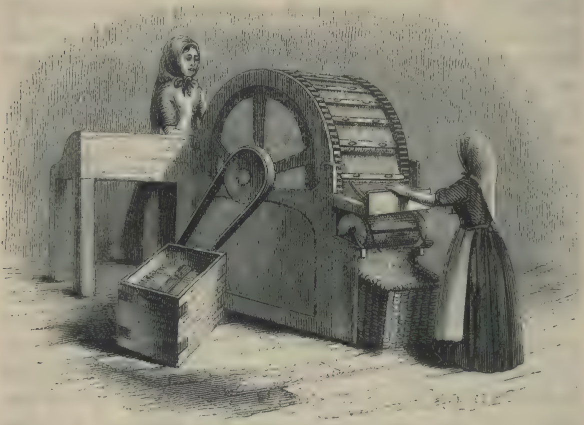
flax is not drawn through them as in working by hand; but, on the contrary, the sharp points or heckles are moved through the flax properly secured. In the large flax mills, the heckling is almost entirely performed by machinery. At Messrs. Marshall's mill, the flax having been divided into lengths of about ten or twelve inches, as already described, a certain quantity is taken, spread out to a breadth of six or seven inches, and fixed in an iron vice or holder. A number of these are then conveyed to a sort of revolving drum, and hooked on



at distances of a few inches from each other, their unsupported ends falling on an internal drum covered with sharp heckling teeth, and revolving with considerable velocity, and in a contrary direction to the external one, the motion of which is rather slow. When one machine has performed its work, the holder is thrown off upon a kind of rail, from which an attendant boy or girl, called the *machine minder*, removes it to the second heckling machine, where the other side of the strick is heckled; from the second it is removed to a third, where the points are finer, and so on, until the line is sufficiently fine for the purpose required. In some machines the points are so arranged, that the lower ends of the flax in each strick are first acted upon, and as the strick advances, the middle part, and lastly, the whole length of the hanging fibres are gradually brought on to the heckles, and both sides of the strick heckled at the same time. By this progressive action the long fibres are not broken, and a smaller quantity of tow is produced. The holders are then returned to the children to be opened, the stricks of flax are taken out and replaced in an inverted position, the combed ends being turned up, and the uncombed being made to hang down. The holders are then passed through the various heckling machines as before.

The appearance of the flax after heckling is much

changed; the line consists of long, fine, soft, and glistening fibres, of a bright silver-grey or yellowish



HECKLING MACHINE.

colour, and when seen from a short distance has very much the appearance of silk. This alteration is due to the splitting of the fibres by the sharp points, as also to the getting rid of dirt and dust, but especially to the removal of the short loose fibres, or tow, the greatest quantity of which is obtained from the upper part of the original length; a large quantity of the dust escapes into the room, the rest gets entangled with the tow, which must be removed, or it would soon choke up the spaces between the heckle points, and prevent their further action; a series of brushes are therefore provided, fixed upon wooden cylinders, which are constantly revolving while the machine is in action; and the bristles of these brushes passing between the points of the heckles, remove the tow or other loose matter therefrom. As tow is very similar to cotton in its fibre, cotton machinery in a modified

form, has been applied with great success to the spinning of tow; the tow is therefore transferred from the brushes to a revolving drum, covered with cards, as in the cotton carding engine, and from this drum the carded tow is removed by a crank and comb: it is then carded a second time, and leaves the second carding engine in the form of a continuous sliver. This is next transferred to the drawing frame, and extended by means of rollers in the usual way, the fibres being laid parallel by means of a series of gills or heckling points. The slivers being properly doubled and drawn, are formed into rovings, and then wound upon bobbins, after which it is spun into a fine but not very strong thread.

The operations of dividing and heckling the flax, which are performed in the same room, occasion rather a dense cloud of dust and loose particles. The girls protect their hair from this dust by wearing a handkerchief tied across the head and hanging loosely down the back; this also protects the neck and shoulders, and has a not unpleasing effect. From habit, this head-dress is constantly worn in or out of the factory, serving the purpose of a bonnet, except on Sundays. The writer noticed this habit in Yorkshire only, and not in the cotton mills of Lancashire, where it would seem to be equally necessary and useful.

The shrieking noise of the dividing engine and the dust of the heckling machine make this room the most unpleasant in the whole of this extensive factory; but as the work is performed almost entirely by children (the number of which varies from two to three hundred), who all work short time (one half of them being at school while the rest are at work), the effect is not nearly so injurious as it would be if the whole day was spent in this clouded atmosphere.

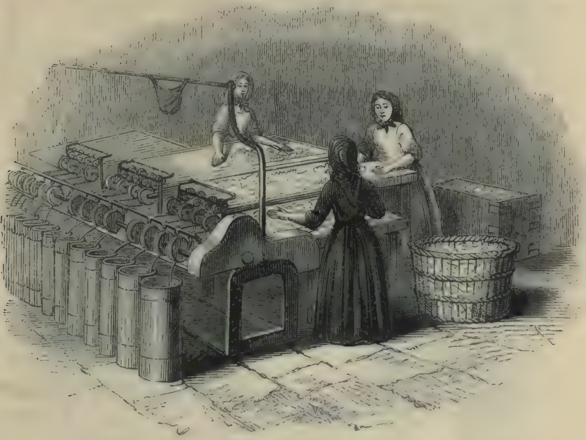
SORTING.

The heckled flax, or *line,* is removed to another room to be sorted. Sorting is an operation in which the sense of feeling is cultivated to a remarkable extent, the *line-sorter* judging of the various degrees of fineness by the touch rather than by the eye, and by this means separating the stricks of heckled flax into several divisions, according to their fineness. The line-sorter is placed before a *sorting-box,* which is a kind of table, containing several boxes or divisions for receiving the various qualities of line, which are called 2 lbs, 3 lbs, $3\frac{1}{2}$ lbs, 4 lbs, 5 lbs, $5\frac{3}{4}$ lbs, $6\frac{1}{2}$ lbs, &c., from an old method of comparing fineness and weight, which will be further noticed when we come to speak of reeling. In the course of sorting, the line is frequently drawn through a block heckle, which stands on the table in order to keep the fibres parallel. The tow is also sorted into qualities, preparatory to spinning.

SPREADING, DRAWING, AND ROVING.

The heckled flax, or line, is next converted into ribands or slivers. For this purpose it is placed upon a feeding-cloth, in such a way that the ends of the second strick reach the middle of the first. This is necessary to preserve a uniform thickness, because the heckled stricks are thicker in the middle than at the ends. The flax is then passed between one pair of rollers, which deliver the whole through gills, or heckling points, to a second pair, which, moving with much greater speed than the first, increase the length and diminish the thickness of the flax. During this operation the flax receives no twist, but is converted into a flat narrow tape or riband, and received into a tin can. When the can is full it is taken to a drawing-frame, where a number of slivers being united, are drawn out into

one length equal to the sum of the united lengths, the effect of which is to produce great uniformity, by



SPREADING-FRAME.

absorbing and correcting the defects of separate slivers, as was explained in noticing the drawing-frame of the cotton-mill. At Messrs. Marshall's mill there were three sets of drawing-frames, at the first of which eight slivers were drawn into one; at the second, twelve into one; and at the third, fifteen into one. The first drawing, or *spreading*-frames, as they are called, were attended to by young women, each of whom had the charge of four. The slivers receive a slight degree of twist at the roving-frame, and are wound upon bobbins preparatory to spinning.

SPINNING.

The invention of large and complicated machinery, and the consequent introduction of the factory system, have had the effect of banishing the flax and cotton spinning-wheel, as well as the hand-loom,

from the cottage of the weaver. During many centuries, the production of linen was so common that it

THE FLAX SPINNING-WHEEL.

might have been almost considered as the national manufacture. Before the establishment of factories, "the spinning of yarn by hand was the ordinary occupation of the females of almost every family in the province of Ulster connected with the linen weaving. It was a constant source not only of employment, but of fair, and sometimes even liberal profit, and of a nature eminently adapted to the social and physical capabilities of those who followed it."* But by the substitution of mill-spun yarn for the hand-spun, the families of weavers have been thrown idle. Mr. Muggeridge was told that "formerly a hand-spinner

* Report of R. M. Muggeridge, Esq., on the Linen Manufactories of Ireland.

would get 4*d.* a hank; now 1½*d.* would be the outside, even if they could get the yarn to spin, which they frequently cannot." Another intelligent witness says: "A pound of flax will come to 1*s.*; you would not get more than five hanks out of that, and that quantity could not be spun under a week by hand. The pound of flax, to spin, which costs 1*s.*, would not be worth more than 1*s.* 8*d.*; this would give but 8*d.* for the spinning, which will show that it is not likely there will be much hand-spun yarn, it is so poor a remuneration for industry. The price is from 3½*d.* to 4½*d.* a hank for coarse; the average price, therefore, is 4*d.*; there are four hanks to the spangle. I remember the time when I have myself paid 5*s.* for the spangle, which is now but averaging 10*d.*"

But if the introduction of the factory system has crippled one branch of industry, it has opened or extended many others. To say nothing of the increased employment to builders, machine-makers, workers in iron, &c. the factories employ a much larger number of persons than had been at any former period engaged in the production of linen yarn and cloth; while as regards abundance of supply, excellence and cheapness of quality, the consumer has greatly gained. That the change has produced much individual suffering there can be no doubt. Operatives find it difficult to adjust their position to altered circumstances; they persist in maintaining a hopeless contest with capital and machinery, instead of searching out other sources of employment. The increased demand for flax will, it is hoped, transfer the labours of the hand-loom weaver from the shed to the field, where he may be profitably employed in cultivating the crop, and afterwards preparing it for the manufacturer. The society for the promotion and improvement of the growth of flax in Ireland have already done much in this respect; and if they can only get the Irish farmer to bestow the proper care and attention upon

the cultivation, there can be little doubt that the regrets of the hand-spinner and weaver will be heard no more.

The spinning of flax does not differ essentially from the throstle spinning of cotton, except in one particular: as the fibres of flax have not the same tendency to entangle themselves together, as in cotton, it is necessary to moisten them with water to make them adhere to each other during the process of spinning, and also to render them more pliable and easy to twist. This practice is supposed to have been derived from the housewives, who were accustomed to moisten their yarn with their saliva at the domestic wheel. Until within a few years, cold water was used for wetting the flax for machine-spinning; but the substitution of water at the temperature of about 120° has been found to be a great improvement; allowing a much finer, smoother, and more uniform thread to be spun, and permitting a given weight of flax to be spun to double the length that it formerly could when cold water was used. The warm water is contained in a trough which runs the whole length of the spinning-frame, and the rapid motion of the spindle causes a dewy spray to be continually thrown off, and as the frames are placed tolerably near together, the attendants were constantly exposed to a minute shower, which in an hour or two would completely wet their clothes. This very serious evil has, however, been remedied by the use of waterproof aprons. To a stranger the hot steaming atmosphere and the wet floor of this room produce an unpleasant effect; but the writer was told that this room was the healthiest in the factory, an assertion which the good looks of the attendants certainly seemed to warrant.

The yarn is made into linen thread by doubling; and after being bleached, it is formed into balls, or wound into reels in the same manner as cotton. The yarn itself is wound upon reels, and then made up

into leas, hanks, bundles, and bunches, according to the following tables given in Mr. Marshall's invoice:

$2\frac{1}{2}$ Yard Reel.

120 threads of $2\frac{1}{2}$ yards	= 300	yards, or 1 lea.
10 leas	= 3,000	yards, or 1 hank.
20 hanks	= 60,000	yards, or 1 bundle.

(3 bundles are usually put together in 1 bunch.)

$1\frac{1}{2}$ Yard Reel.

100 threads of $1\frac{1}{2}$ yards	= 150	yards, or half a lea.
10 half leas	= 1500	yards, or 1 hank.
40 hanks	= 60,000	yards, or 1 bundle.

(6 bundles are usually put together in 1 bunch.)

The size or fineness of linen yarn is reckoned by the number of leas to the pound weight. Twenty years ago the average number of leas per pound did not exceed 15; but according to Mr. Marshall's communication to Mr. Muggeridge, the factory inspector, "the common limit of fineness of linen yarn spun by machinery may now be considered to be about 150 leas;* and all used for different descriptions of common linens, and not sufficiently fine for the manufacture of cambrics or thread for lace."

"We now spin," says the same excellent authority, "a small proportion of yarn of 150 to 240 leas, used in the manufacture of lawns and coarse cambrics, in the neighbourhood of Belfast.

"Improvements continue to take place in the various departments of flax spinning, for the most part gradually, but with every prospect of continuance; leading to the anticipation that, in the course of a moderate term of years, all degrees of fineness of linen yarn now spun by hand up to 300 and 400 leas, may be spun by machinery."

In noticing the method of sorting line, it was stated, that the various qualities were divided into 2, 3, $3\frac{1}{2}$, &c. pounds, from an old method of com-

* This was written in the year 1839.

paring fineness and weight. In linen yarns, the bundle of 60,000 yards is sometimes called by its number of leas per pound, or by the weight of the bundle. For example; a bundle of 25 leas to the pound, weighs 8 lbs.; a bundle of 50 leas to the pound, weighs 4 lbs.; a bundle of 100 leas to the pound, weighs 2 lbs., and so on; so that 8 lbs. and 25 leas, and 4 lbs. and 50 leas, and 2 lbs. and 100 leas, are synomymous terms, as far as the size is concerned. Now, in sorting, a certain quality of line will spin to a certain size, or weight, per bundle; and it was formerly the custom of the line-sorters to call certain qualities 2 lbs., 3 lbs., $3\frac{1}{2}$ lbs., 4 lbs., &c., because that quality of line would spin to that weight per bundle. The same standard and name are still retained by line-sorters for the same quality of line, but from improvements in machinery, and other causes, $5\frac{3}{4}$ lbs. line can now be spun to the size of 3 lbs. the bundle, and finer.

STATISTICS.

THE statistics of the linen trade will be more in place in the treatise on the manufacture of woven goods, but there are a few details which may find a place here.

So long as the production of linen yarn was confined to the spinning-wheel, linen was a costly article, and the trade necessarily very limited; a remark which applies equally to the cotton trade. The latter owes its present triumphant position to the invention and improvement of those admirable machines which reflect so much credit on the mechanical genius of this country; and the linen trade began to improve as soon as advantage was taken of these machines and applied to the production of linen yarn. Mr. Marshall says that "before the flax was spun by machinery, the French and Belgian spinners were so superior to any thing that we had in this country or

in Ireland, that the linens were a great part of them imported from Flanders or from the north of Europe."

Mills for spinning flax were first constructed at Darlington about 50 years ago; and the improvements which have been made in it, and in bleaching, &c. have raised the British trade to the same level, and even above that of the foreigner, so that besides supplying our own markets, we now export largely.

In the year 1844, were exported from Great Britain and Ireland 25,970,569 lbs. of linen yarn, of the declared value of 1,050,676*l.*

In the same year was imported of flax and tow, or cordilla of hemp and flax, 1,513,494 cwts., nearly the whole of which was retained for consumption.

The principal flax-mills in England are in the West Riding of Yorkshire and its immediate vicinity, and in Lancashire, Dorset, Durham, and Salop. In Scotland, Dundee is the chief seat of this trade, as is Belfast, in Ireland.

A few years ago Mr. Marshall stated that the trade had doubled in England, and trebled in Scotland, within the last 45 or 50 years; and the improvements in machinery had been such, that in order to keep pace with them he had reconstructed his mill twice within the same period. This must have been a costly proceeding, since the number of persons employed by him amounts to above two thousand.

Messrs. Marshall's flax-mills are situated at a place called Holbeck, in the immediate neighbourhood of Leeds. The buildings occupy a very large extent of ground, and present the usual features of factories —namely, lofty square buildings of many stories, with a tall chimney. But there is one of the mills ("the new mill") which does not fall under the above remark; it is not a lofty building of many stories, the stories being, so to speak, all placed side by side, to form one enormous room, 396 feet long by 216 wide, equal to nearly two acres. This magnificent room is five times larger than Westminster Hall, and seven times larger than Exeter Hall, London. It was

stated at one of the meetings of the Institution of Civil Engineers, a few years ago, when the construction of this "one story mill" was described, that Mr. Smith, of Deanston, was the first to adopt this form of factory, and Mr. Marshall the second; and the advantages resulting from the plan were stated to be "convenience of supervision, facility of access to the machines, the power of sustaining uniformity of temperature and moisture, the absence of currents of air, which are so objectionable in other mills, the simplicity of the driving gear, and the excellent ventilation, which is so desirable for the health of the work-people."

Some idea may be formed of the interior of this noble room from the frontispiece. The machinery is arranged in parallel lines, extending the whole length of the room, ample space being left between and among them for the attendants. The processes carried on in this room are chiefly drawing, roving, spinning, doubling, and reeling; the dusty operations of dividing and heckling being confined to the old mill. Hot water spinning is also carried on in this room, but the steam is not so much seen as in the room already noticed, in consequence of improvements in the spinning-trough, better valves for the admission of steam, a greater space for its escape, and better ventilation. The machines are mostly attended by young women; and a tablet attached to each machine states the number of spindles at work, the quality of yarn being spun, or some other particular information belonging to the work.

The lightness and airiness, warmth and ventilation, of this room are beyond all praise. The light is derived from the roof, which is formed of brick groined arches, sixty-six in number, each thirty-six feet span; and supported by iron pillars to the height of twenty-one feet. In the centre of each arch is a conical skylight, about fourteen feet in diameter, and rising about ten feet above the roof. From the points of these lights the used air of the room is allowed to escape.

Beneath this room is an immense vaulted cellar, with brick pillars. This cellar is employed for a variety of useful purposes; one of which is to supply hot air to the room above. This is done by means of a small steam engine working a large fan, which forces air through a series of 364 pipes, contained in two large steam-chests, which heat the air before it ascends into the mill. The temperature can be regulated by the quantity of steam which is admitted into the chests, or by allowing a portion of cold air to pass by without traversing the pipes. Valves and doors in the flues permit any temperature which is desired to be obtained, or that degree of moisture which is essential in the process of flax spinning.

The cellar also contains the shafts for communicating motion to the immense assemblage of machines in the mill. These shafts are moved by a pair of steam engines of 100 horses' power. This cellar also contains the gas and water pipes; carpenter's shop and warehouses; and among its miscellaneous contents the writer was pleased to notice an arrangement for promoting the health and comfort of the work-people; namely, a set of baths, for both hot and cold water. The operatives are entitled to the use of them on exhibiting a ticket of good conduct from the over-looker. The cold baths are gratis, but for a warm bath one penny is charged. Each bath is contained in a separate room, which is lighted with gas; and the whole is under proper regulation and control.

But if the general and particular details of this two acre room and the immense cellar beneath it are calculated to delight and instruct the observer, a visit to the roof will certainly create the liveliest admiration. On ascending a flight of steps within the room we come out, not upon an ordinary flat roof, but into a grass field, from the surface of which rises a number of what, at first sight, appear to be green-houses, but on approaching them, the whirl of the machinery below shows that they are the sky-lights already noticed. The presence of a grass field

in so novel a situation, admits of easy explanation. The brick arches which form the roof of the great room were first covered, on the outside, with a coating of rough plaster, then with an impervious coating of coal-tar and lime, and to prevent this from cracking, a layer of earth, eight inches thick, was placed upon it, and sown with grass, which flourishes so well that sheep are occasionally sent up to feed upon it. The method of draining this two acre field is not the least admirable contrivance in this remarkable building. The iron pillars which support the roof are hollow pipes, down which the rain water passes into the sewer beneath. The upper extremity of each pipe is covered with a grating, to prevent solid substances from entering and stopping up the channel.

Even the entrance to this building is peculiar. It represents the front of an Egyptian temple, nicely cut in stone; and the lofty chimney, which towers above the whole, closely resembles the celebrated Cleopatra's needle, whose name it bears, and is a conspicuous land-mark to the stranger approaching Mr. Marshall's factory from a distance.

THE ROOF OF MARSHALL'S ONE-STORIED FLAX MILL

THE MANUFACTURE OF

WOOLLEN AND WORSTED YARNS.

HISTORICAL NOTICES OF THE WOOLLEN MANUFACTURE.

NEXT to the skins of animals, the wool of the sheep was probably among the earliest substances used for clothing. The tendency of woollen fibres to unite, or *felt,* into a kind of coarse cloth could not have escaped attention; and advantage was doubtless taken of it at a very early period. From several passages in Scripture, it appears that the art of spinning and weaving wool was known in the time of Moses, 1450 before the Christian era. Among the ancient Greeks and Romans the woollen manufacture had attained considerable perfection; and it has been supposed that the latter people introduced it into Britain on their conquest of the island. They seem to have established a woollen manufactory at Winchester, for supplying cloth to the Roman army; but it is not imagined that they introduced the sheep also; but, finding the animal here, they employed the wool for their own purposes. Indeed, a Roman writer, quoted by Hollinshed, says, "The wool of Britain is often spun so fine that it is, in a manner, comparable to the spider's thread." It does not appear, however, that woollen garments were in very great request in Britain: the Saxons wore garments of leather, and for many years after the conquest the costume of the

peasants was of the same material, and the "buff jerkin" is supposed to have continued in use as the ordinary dress of the labouring people of England until the time of the Commonwealth.

The first express mention of the sheep in this country occurs in a public document of the year 712, where it is merely stated that the price of the animal was one shilling, until a fortnight after Easter. After this date, no mention is to be found of the woollen manufacture until the time of Alfred, when the mother of that great sovereign is described as being skilled in the spinning of wool, and busied in training her daughters to the same employment. This seems to have become a common occupation among the higher classes; for at a later period, it is remarked of Edward the Elder, that being careful his children should receive a proper princely education, "he sette his sons to scole, and his doughters he set to woll-werke." Indeed, the very name by which unmarried women in England are designated,—"spinster,"—is a proof of the antiquity of this mode of employing their time.

Such notices as these, however, tend to show that the art of spinning and weaving wool was a *domestic* rather than a *national* employment. The origin of the woollen manufacture as a national branch of industry is said to have arisen in the time of William the Conqueror, when a large number of the Flemings, being obliged to quit their own country by an incroachment of the sea, came to England, hoping for protection from the queen, who was a native of their country. They were well received in England, and the king stationed a number of them upon the northern frontiers, chiefly about Carlisle. Henry I., however, finding the Flemings did not agree well with his other subjects, removed them to a district taken from the Welch, now forming part of Pembrokeshire. They are described as "a brave, hardy people, equally qualified to handle the plough and the sword;

and they were also skilful in the woollen manufacture, the great staple of their country; so that in every respect they were a most valuable colony, whether considered as a barrier against the enemy, or the first founders of the manufacture of fine woollens in England."

Henry II. granted a fair for the clothiers and dressers, to be held in the Churchyard of Bartholomew Priory, near Smithfield, for three days, which spot is still called "Cloth Fair." Towards the end of the reign of this sovereign, the woollen manufacture became widely extended over the kingdom, companies of weavers being established in Oxfordshire, Yorkshire, Nottinghamshire, Huntingdonshire, Lincolnshire, and Winchester, all paying fines to the king for the privilege of carrying on their manufactures, to the exclusion of all other towns. There were, however, dealers in other towns, who paid fines to the king for the privilege of freely buying and selling dyed cloth. Henry II. gave the weavers of London a confirmation of their guild, and in the patent directed that, if any weaver, in making cloth, mixed Spanish wool with the English, the chief magistrate of London should burn it. The prosperity of the woollen trade was not destined to continue; for the troubles and wars during the reigns of John, Henry III., Edward I., and Edward II., nearly ruined it. It was revived by Edward III. At the beginning of this reign, one John Kemp, a Flanders cloth-worker, received a license to establish himself in this country. Accordingly he settled, with a number of dyers and fullers, at Kendal, in Westmoreland, where his name appears to this day. The cloth called "Kendal green," afterwards became celebrated. It is mentioned by Shakspere in his play of Henry IV.

The success of Kemp probably led Edward III. to desire the presence in England of more of his industrious countrymen; for we learn from Fuller's Church History, that a number of them were invited over.

As the passage in Fuller's work is amusing, we quote it, with a few omissions, not forgetting the learned author's reason for dealing in such matters in a work apparently unsuited to them: for he says, they "reductively belong to the 'Church History,' seeing many poore people, both young and old, formerly charging their parishes, were thereby enabled to maintain themselves."

"The King and State began now to grow sensible of the great gain the Netherlands got by our English wool, in memory whereof the Duke of Burgundy, not long after, instituted the order of the Golden Fleece, where indeed the Fleece was ours, the Golden theirs, so vast their emolument by the trade of clothing. Our king, therefore, resolved, if possible, to reduce the trade to his own country, who as yet were ignorant of that art, as knowing no more what to do with their wool than the sheep that weare it, as to any artificiall and curious drapery, their best cloathes then being no better then freezes, such their coarseness for want of skill in their making. But soon after followed a great alteration, and we shall enlarge ourselves in the manner thereof.

"The intercourse now being great betwixt the English and the Netherlands (increased of late since King Edward married the daughter of the Earl of Hainalt), unsuspected emissaries were employed by our king into those countries who wrought themselves into familiarity with such Dutchmen as were absolute masters of their trade, but not masters of themselves as either journeymen or apprentices. These bemoaned the slavishnesse of these poore servants, whom their masters used rather like heathens than christians, yea, rather like horses than men. Early up and late in bed, and all day hard work and harder fare, (a few herrings and mouldy cheese,) and all to enrich the churles their masters without any profit unto themselves.

"But, oh! how happy should they be if they would

but come over into England bringing their mystery with them which would provide their welcome in all places. Here they should feed on fat beef and mutton till nothing but their fulnesse should stint their stomachs: yea, they should feed on the labours of their own hands, enjoying a proportionable profit of their pains to themselves. * *

"Liberty is a lesson quickly conn'd by heart, men having a principle within themselves to prompt them in case they forget it. Persuaded with the promises, many Dutch servants leave their masters and make over for England. Their departure thence (being pickt here and there,) made no sensible vacuity, but their meeting here altogether amounted to a considerable fulness. With themselves they brought over themselves and their tools, namely, such which could not, as yet, be so conveniently made in England.

"Happy the yeoman's house into which one of these Dutchmen did enter, bringing industry and wealth along with them. Such who came in strangers within their doors soon after went out bridegrooms, and returned son-in-laws, having married the daughters of their landlords who first entertained them. Yea, these yeomen in whose houses they harboured, soon proceeded gentlemen, gaining great estates to themselves, arms and worship to their estates.

"The king having gotten this treasury of foreigners, thought not fit to continue them all in one place, lest in discontent they might embrace a general resolution to return, but bestowed them through all the parts of the land, that cloathing thereby might be the better dispersed."

The historian then gives a list of the places where the foreigners settled; from which it appears that woollen fustians were made at Norwich, baizes at Sudbury, broad cloths in Kent, kerseys in Devon, friezes in Wales, cloths in Worcestershire, Gloucestershire, Hampshire, Sussex, and Berkshire; coarse cloths in the West Riding of Yorkshire, and serges

at Colchester in Essex, and Taunton in Devonshire. Then after stating that "a prime Dutch cloth-maker in Gloucestershire had the sirname of Web given him by King Edward Third;" he continues:

"Here the Dutchman found Fuller's earth a precious treasure, whereof England hath, if not *more*, *better* than all Christendom besides; a great commodity of the quorum to the making of good cloth, so that nature may seem to point out our land for the staple of drapery, if the idleness of her inhabitants be not the only hindrance thereof.

* * * *

"And now was the English wool improved to the highest profit, passing through so many hands, every one having a fleece of the Fleece, sorters, kembers, carders, spinsters, weavers, fullers, dyers, pressers, packers, and these manufactures have been heightened to a greater perfection since the cruelty of the Duke de Alva drove over more Dutch into England."

It has been remarked of Edward the Third's encouragement of the wool trade, that "although historians have been strangely forgetful of this the most glorious achievement of his reign, he recalled, re-established, and would have established for ever the staple manufacture of his country, and the most effective source of her power. If the wars of the Roses which succeeded, once more reduced the woollen manufacture to the state in which he found it, the fault was not his."* The parliament which assembled in the year 1337, when this monarch was only twenty-five years of age, enacted that no wool of English growth should in future be exported. This apparently deprived the king of a national source of revenue, the export duties on the much prized British wool having long produced a large revenue; but the king wisely consented to make the apparent sacrifice. The parliament also forbade the importation of foreign cloth, prohibited any one from wearing it, and ordered a tax of twenty

* Youatt, on the Sheep.

shillings on every sack of wool employed in the home manufacture. The consequence of this was, that by the end of the first year, the king had a greater revenue than before, and based on a surer foundation. The home manufacture prospered and had its effect on the grower of the wool. The flocks of sheep rapidly increased, and the supply of wool soon became greater than the home market could dispose of; therefore, at the joint entreaty of the grower and the manufacturer, wool was again allowed to be exported, and from this quarter also a considerable revenue was obtained.

The trade was now in so healthy a condition as to be above the fear of competition. The next step, therefore, was to throw it open to all countries; British wool was allowed to be exported, and foreign cloth to be imported on payment of a certain tax. When the English wool again began to find its way to Flanders, it readily sold for almost any price the merchants chose to ask for it.

Wool now became the representative of money; when gold was scarce, public transactions were made in wool, which found a ready market everywhere. Thus we read, that in 1342 the king sent a large number of sacks of wool to Cologne, in order to redeem Queen Philippa's crown, which was pawned there for 2,500*l.*

As the woollen trade increased, various impositions began to be practised, to prevent which an *alnager*, or sworn officer, for the inspection of woollens was appointed.

In the 13th Richard II. the exportation of wool was prohibited to the natural subjects of the kingdom, and the privilege granted only to certain foreigners. The consequence of this was, that the stock of wool accumulated, and its price fell; this occasioned great murmurings, and the export trade was thrown open as before; but British wool did not again recover its former high price; Spanish wools were getting into repute, and were employed extensively in the manu-

facture of broad cloths. The fashions of the times changed too; there was more demand for a peculiar kind of goods called *worsted*, from the name of a small town in Norfolk, where the manufacture was first set on foot, in the reign of Edward II., or perhaps earlier.* The general use of worsted goods "would speedily influence the character of the fleece. The intelligent agriculturist knows well how to grow the wool which the fashion of the day requires; and now probably began a change in the character of the sheep in France, in the Netherlands, and in England. The Romney Marsh and the Lincoln, if they did not then spring, as it were, into being, were at least more diligently cultivated, and the older fine-woolled sheep were to a lamentable degree abandoned."†

The British long wools continued to be superior to those of foreign growth, for which reason attempts were made to export not only the British fleece but the sheep also. This ruinous practice was checked by laws of Henry VI., passed in 1425, and again, in the 8th Elizabeth, which imposed very severe penalties on those who should be found guilty of the practice. Nevertheless we read of our sheep being sent out of the country under royal authority. In 1464 a present of Cotswold rams was sent by Edward IV. to Henry of Castille, and in 1468 another flock was shipped for John of Aragon. They were designed to improve the long-woolled breed of Spain. These do not appear to have been the only occasions on which sheep were sent from England to Spain, for it is said that the celebrated Spanish breed called *Merino* obtained this

* In the reign of Edward III., the worsted trade shared in the general prosperity of the woollen trade. The quantity of worsted yarn spun in Norwich and its neighbourhood, was not, for some time, sufficient for the home supply; and in 1348, the exportation of these yarns was prohibited. In a few years afterwards, worsted yarns were, however, exported in considerable quantities, and the manufacture rapidly extended through the whole of the county, and thence to Suffolk and Cambridgeshire, southward; to the midland counties, westward; and to Yorkshire, towards the north.

† Luccock on Wool.

name, from *Marino,* because the original breed of sheep was imported *by sea* from England in the reign of Henry II. Edward IV. also, towards the close of his reign, granted permission for his sister Margaret, Duchess Dowager of Burgundy, yearly, during her life, to export from England, free of all duty, 1000 oxen and 2000 rams to Flanders, Holland, and Zealand. Her object was, doubtless, to improve the breeds of cattle and sheep in those countries; but the king seems to have forgotten how deeply he wounded the commercial interests of his kingdom, which depended in a great measure on the demand for British wool in the Flemish marts. "The resemblance between the cattle on the two shores is thus well explained; and the traveller will cease to wonder that on the northern coast of France, and through nearly the whole of Flanders, he thinks that he finds again the identical sheep of the Kentish pastures."*

During the reigns of Henry VII. and Henry VIII. the wool trade was in a declining state. The once celebrated British short wool no longer kept the lead of the market at home, while abroad, many a successful rival had sprung up. Some of the old breeds of fine woolled sheep seem to have disappeared altogether. Still, however, we read of a few celebrated master manufacturers, among whom was John Winchcombe, better known as Jack of Newbury: he kept a hundred looms constantly at work, and some idea of his wealth and influence may be formed from the fact, that he sent to Flodden Field sixty soldiers fully equipped at his own expense.

One of the causes which injured the woollen-trade was a system of monopolies, established during the reign of Henry VIII., of the manufacture of certain articles in certain towns to the exclusion of the whole country besides. In a memorial from the City of York, it was stated that the making and wearing of coverlets, had long occupied the poor of that city,

* Youatt.

but that the manufacture having spread into other parts, was thereby disgraced and discredited. Whereupon it was decreed that none should make coverlets in Yorkshire, but inhabitants of the City of York. In the same way worsted was declared to be "the private commodity of the City of Norwich." Worcester preferred a complaint similar to that of York; whereupon it was enacted that the peculiar manufacture of Worcester should be restricted to that city and four other towns.

In the year 1530, the 25th of Henry VIII., the spinning-wheel was invented, it is said, by Jurgen of Brunswick. This was an important aid to the woollen manufacture, and may have contributed to its revival towards the close of this reign. We do not find much respecting it during the short reigns of Edward VI. and Mary; but in the reign of Elizabeth, it naturally shared in the prosperity of the kingdom. "Elizabeth continued to pursue that cautious and wise policy, to which she was indebted for the success that attended all the proceedings of her government. The trade, in goods of home manufacture, so rapidly extending, she was urged to prohibit the export of British wool, and thus make the whole secure; but she at once refused. She knew that there could be no better means of diminishing the export of wool, if that were an evil, than the profitable employment of it at home. She gave every encouragement to the manufacturer; she permitted the grower to dispose of his produce as he pleased; and thus established the commerce of her kingdom, on its only just and permanent basis."

The persecutions in the Netherlands, under Philip of Spain and his emissary, the Duke of Alva, drove many of the people out of their country. England being peaceful and powerful under a wise sovereign, was naturally regarded as a land of refuge. No less than five thousand refugees found employment and protection in the City of London, and many others

settled in different parts of the kingdom. The decayed towns of Canterbury, Norwich, Sandwich, Colchester, Maidstone, and Northamptom, were filled with the manufacturers of woollen and silk: the superior machinery, and more skilful manipulation which they introduced, enabled England to send into the market a cheaper and better fabric, thus essentially contributing to the lasting prosperity of the country, in which they found refuge. The manufactures which were principally benefitted by the refugees, were those of light cloth, in which England had hitherto been very deficient, and also in every description of worsted fabric. The export trade was increased considerably, and extended to countries where England had not before traded.

The art of dyeing, which at one time had been perfectly known to the English, seems to have been lost amidst the distractions of the kingdom. At this period it was the practice to send the white cloths into Holland, to be dyed and dressed, and they were then brought back for sale. It was felt to be disgraceful that they, who surpassed all other countries in the fabric of the cloth, could not perform the finishing part at home. The annual sum paid to the Hollanders for finishing our cloth, was calculated at 400,000*l.* A proposal was therefore made by some manufacturers and merchants, in the reign of James I. to undertake the dyeing and dressing of cloth, on certain terms, leaving to the king the monopoly of the sale: the plan was tried, but did not succeed; the cloths were badly dyed, at a charge much higher than was paid by sending them abroad; and the Hollanders, therefore, continued for a time to finish our cloths as before; but the folly and loss of such a proceeding was so apparent, that efforts were renewed to recover the lost art. In the year 1667, a dyer, named Brewer, came from the Netherlands with his workmen, and being well received and assisted by the government, he taught the English manufacturers his art, and soon

made them perfectly independent of the Continent in this respect.

During the civil wars of Charles the First's reign, the trade suffered severely, and gradually fell into neglect. Advantage was taken on the Continent of the supineness of the British, to establish manufactures of fine cloth, which in the course of a few years were enabled to fabricate every kind of goods, which had hitherto been supplied entirely by the English.

With a view to promote the woollen manufacture in this country, by exciting a demand for woollen stuff, a singular law was instituted in 1666, enacting, "that every person should be buried in a shroud, composed of wool alone, under the forfeiture of *5l.* to the poor of the parish." This law continued in force about one hundred and thirty years.

In the year 1685, Louis XIV. of France, revoked the edict of Nantes, or, in other words, severe enactments were put in force against the Protestants in France. More than 600,000 persons left their native country, carrying with them their industry and knowledge to other countries, which were largely benefitted by them. The greater number were welcomed by Holland, Switzerland and Germany, and about 50,000 found their way to England. They greatly improved the lighter branches of the woollen trade, as well as the manufactures of silk, linen, paper, glass, and hats. The whole population had, by this time, advanced in wealth and luxury; cloths of a finer texture were more generally worn; a larger supply of fine cloth was consequently produced, a greater number of sheep were bred, and the staple trade of England again revived.

From this period the history of the woollen manufacture in this country is one of progress. There are, however, some remarkable changes in the supply of the raw material, which deserve a slight notice. In the year 1698, the number of sheep in great Britain was calculated at 12,000,000.

In 1833, it had risen to 32,000,000. The increased demand for wool had been met by a new system of husbandry; namely, the artificial, or turnip husbandry; by means of which, a regular supply of food is provided for every season of the year, so that double, and occasionally treble the number of sheep, compared with former times, can be kept on the same farm. The animals are also fattened quicker, and to a greater extent, and the size of the breed increased. But it was soon discovered by the manufacturer, that as the animal thrived, the fibre of wool became longer and larger, and the goods which used to obtain a ready sale, and which were formerly preferred to those of every other country, could not be disposed of at all, not even in the district where the wool was grown. The purchaser would have a cloth made of Spanish wool only, and, consequently, English wools became greatly reduced in value. The sheep-owner found that he could scarcely sell his wool, and complained loudly to the legislature. A duty on foreign wool was laid and gradually increased, until it was discovered that British wool, although changed in character, had not deteriorated in value; for that which was once a *carding* wool now became a *combing* wool; or, in other words, the short wool once used for fine cloths, had now become a long wool, well adapted to the manufacture of worsteds, and a number of other purposes. Government then threw open the woollen trade altogether, and the British manufacturer once more began to compete with his foreign rival. The British wools, now occupying a new place in the manufacturing scale, a very important export trade in wool, and in worsted yarns, was established, and has been rapidly increasing every year. The demand of late years for long wools has been quite equal to the supply; indeed, the whole supply of Great Britain has not been more than enough for the home and foreign trade, and has not only risen in value since the duty

on foreign wool was repealed, but now bears a full remunerating price.

Previous to the year 1800, the importation of Spanish wool for clothing purposes had not exceeded three millions of pounds annually; but it rapidly increased to eight or nine million pounds. A new market being afterwards opened in the heart of Germany, at which a still superior quality of wool might be purchased, the import increased to no less than thirty-six millions pounds.

The establishment of the cotton manufacture in 1780, somewhat retarded the progress of the woollen trade; but in a short time a permanent good was derived from it, which far exceeded the temporary evil. With the establishment of the cotton manufacture came the introduction of steam-power, of the carding and spinning machines, and those admirable contrivances, the history and description of which have been sketched in a former treatise. These grand improvements were as well adapted for wool as for cotton, and were gradually introduced; the effect of which was to lessen the cost of the manufacture, and, by placing the goods more within the reach of all classes, to increase the demand for them. Probably at no period in the later history of the country was the woollen trade in a more flourishing condition.

ON THE SHEEP

AND

THE GROWTH OF WOOL.

The history of the sheep goes back to the remotest antiquity; for the care of it was committed to the younger son of the first man. "Abel was a keeper of sheep," (Gen. iv. 2.); and these sheep seem to have been horned; for when Abraham had conducted his son Isaac to the mount of sacrifice, and had been forbidden to harm him, he saw "behind him a ram caught in a thicket by his horns." (Gen. xxii. 13.)

The original stock of the various breeds of domestic sheep, is supposed to be the Argali, which is still found wild on the mountains of Siberia and Kamtschatka. In summer its coat consists of short hair, sleek like that of a deer; but in winter it is made up of wool mixed with hair, and concealing at its roots a

fine woolly down. The Argali very much resembles the Moufflon, or wild sheep of the mountain districts

THE ARGALI.

of Sardinia, Corsica, and Asia Minor. By cultivation it gradually loses its horns, and exchanges a hairy for a woolly coat.

The difference between hair, and fur, and wool, can be much better understood than described. It was formerly considered to be one of the distinctions between the goat and the sheep, that the former was covered with hair, and the latter with wool. But this distinction was abandoned when it was discovered that wool is by no means peculiar to the sheep; it being found on many animals at some season of the year. The under hair of some goats was found to be finer than the fleece of any sheep, and to have occasionally the crisped appearance of wool; while in other goats it was so coarse as to be of use only for the lists and edges of cloth. In some of the deer tribe, a portion of wool is found at the roots of the hair, as in the moose deer, or elk. On the Wapiti deer it forms a thick covering, and also on some parts of the hide of the British red deer in winter. Some of the foreign breeds of oxen, as the yak of Tartary, and the ox of Hudson's Bay, yield a fine

and valuable wool. The gnoo, a species intermediate between the antelope and the ox, bears wool; as do also the camel, the dog, and the bear, and many of the fur-bearing animals, as the hare, the rabbit, and the beaver; but as in most of these animals the wool lies concealed at the roots of the hair, it escapes general observation. The fleece of the primitive sheep was probably a mixture of hair and wool, as is still the case with the sheep found in many parts of Tartary, India, China, and Africa. A remarkable change in the fleece is brought about by domestication. Under a temperate climate, more regular and better pasture, and shelter from the weather, the coarse hair gradually disappears, and the shorter and fine wool becomes abundant. Indeed, hair in the fleece (except on the face and legs, and occasionally on the belly) is now considered to result from bad management among domestic British sheep. It is found, however, that in those sheep which are left much to themselves, as on the wilds of Dartmoor, and the mountains of Wales, Westmoreland, and Scotland, the fine and silky wool is often mixed with long hairs.

The varieties of sheep in different parts of the world are now almost innumerable; producing, of course, a large number of different kinds of wool; but for manufacturing purposes, the most important distinction among them all refers to the length of the staple. All wool is referred to one of two classes—the *short* or *carding* wool, which is used in the manufacture of broad-cloths; and the *long* or *combing* wool, which is used for *worsteds:* each of these classes is subdivided into a variety of sorts, according to their fineness and the length and soundness of the staple, and other particulars which will be noticed further on. (See page 34.)

Particular districts have been for ages celebrated for the superior character of the wool grown in them: this is owing, in a great degree, to food and climate. It is known that the wool of sheep fed in chalky dis-

tricts is greatly inferior to that of the same sheep pastured on land of some other kind. Bad herbage also produces inferior wool; and a marked improvement will be observed in the fleece, if the sheep are moved to better pasture only a month before shearing. "Suppose half a flock of South Down sheep reared in the centre of the South Downs (known to be calcareous and chalky land), and the other moiety transferred to some of the rich land found in the neighbourhood of Pevensey Level, near Lewes. The contrast that would be perceptible in the fleeces of these two portions of the same flock, when shorn, is inconceivable to those who have not had an opportunity of witnessing the powerful influence of a change in pasture on the wool of sheep. Both the temperature of climate, and herbage, have an evident effect on wool, as may be seen in England, on that of those flocks pastured within a few miles of the sea-coast, beginning with the Isle of Sheppey, round the coast of Kent, Sussex, and Hampshire. The wool of flocks which are fed within ten miles of the sea-coast, generally possesses a longer staple, and more pliancy of texture, and consequently it is better adapted to the use of the spinner than the produce of the same flock pastured farther in the interior, on similar soil. This difference I am disposed to impute to the exhalations arising from the sea, which, like the smoke of London, extend inland at least ten miles; thus operating on the herbage as well as on wool."*

The wool, as it grows on the back of the animal, is nourished by a peculiar secretion from the glands of the skin, which, from its adhesiveness and colour, is called the *yolk*. It serves the further purpose of matting the wool together, so as to form for the animal a secure defence against wet and cold. It is found in greatest quantity about the breast and shoulders, where the best wool is most abundantly produced. It differs in quantity in different breeds:

* Southey, on the Sheep.

it is very abundant on the Merinos, and sufficiently plentiful on most of the southern breeds, either to assist in the production of the wool, or to defend the animal from the wet and cold. The medium quantity of yolk on a Hereford, Shropshire, or Sussex sheep, is about half the fleece, and this is the customary allowance to the wool-buyer, if the fleece has been sold without washing. The softness and flexibility of the living fleece depend upon the presence of the yolk; but as it does not add to the value of the shorn fleece, it should be washed out, which can easily be done in a running stream, as the yolk is a true soap, and is soluble in water. In Britain the sheep are

SHEEP-WASHING.

washed before shearing. If the yolk is left in the fleece it ferments, and leaves the wool in a hard and harsh state.

The filaments of white wool, when properly cleaned, are semi-transparent; their surface, in some places, is beautifully polished, in others curiously encrusted, and they reflect the rays of light in a very

pleasing manner. This exterior polish varies much in different wools, from the same breed of sheep, at different times. When the animal is in good condition, and the fleece healthy, the appearance of the fibre is really brilliant; but when the sheep has been half starved, the wool has a dull dingy appearance. The wool which has been cut from the dead animal is also harsh and weak, and incapable of taking a good dye. In commerce wools are distinguished as *fleece* wools and *dead* wools; the first being obtained from the annual shearing of sheep; the latter from the dead animal. The best wools are generally those which are shorn towards the end of June, or the beginning of July.

SHEEP-SHEARING.

The description of sheep which has been most sought after, and by which so many countries have been enriched, is the Merino, or migratory sheep of

Spain. Some years ago, it was calculated that the number of these migratory sheep amounted to ten millions. Twice a year, in April and October, they are led a journey of about four hundred miles, passing the summer in the mountains of the north, and the winter on the plains towards the south. The excellence of the wool, to which every thing else is sacrificed, is supposed to be due to an equality of temperature maintained by shifting the position of the sheep, so that they may occupy the cooler mountains in summer, and the warmer plains in winter. An objection to this explanation arises from the fact, that the fleece of some of the German merinos, which do not travel at all, is far superior to the best Leonese fleece; and even in Spain it is said that there are stationary flocks which produce wool equal in quality to that of the migratory ones.

The first impression made by the merino sheep on one unacquainted with its value would be unfavourable. The wool lying closer and thicker over the body than in most other breeds of sheep, and being abundant in yolk, is covered with a dirty crust, often full of cracks. There is also a coarse and ugly patch of hair on the forehead and cheeks, which is cut away before shearing time. There is also a singular looseness of skin under the throat, giving a remarkable appearance of hollowness in the neck. The pile, when pressed upon, is hard and unyielding, in consequence of the thickness with which it grows on the pelt, and the abundance of the yolk detaining all the dirt and gravel which falls upon it: but when examined, the fibre is found to exceed in fineness, and in the number of serrations and curves, that which any other sheep in the world produces. The average weight of the fleece in Spain is eight pounds from the ram, and five pounds from the ewe. "The excellency of the merinos consists in the unexampled fineness and felting property of their wool, and in the weight of it yielded by each individual sheep;

the closeness of that wool, and the luxuriance of the yolk, which enables them to support extremes of cold and wet quite as well as any other breed; the easiness with which they adapt themselves to every change of climate, and thrive and retain, with common care, all their fineness of wool under a burning tropical sun, and in the frozen regions of the north; an appetite which renders them apparently satisfied with the coarsest food; a quietness and patience into whatever pasture they are turned, and a gentleness and tractableness not excelled in any other breed."*

The periodical journeys taken by these sheep in Spain can be traced back to the middle of the fourteenth century, when a tribunal, called the Mesta, was established for their regulation, consisting of the chief proprietors of these migratory flocks, the king being the merino mayor. It established a right to graze on all the open and common land that lay in the way; it claimed also a path, ninety yards wide, through all the enclosed and cultivated country, and prohibited all persons, even foot passengers, from travelling these roads when the sheep were in motion.

The flocks are divided into detachments of 10,000 each, under the care of a mayoral or chief shepherd, who has under him fifty shepherds and as many huge dogs. The mayoral precedes the flock, and directs the length and speed of the journey; the others, with the dogs, follow and flank the cavalcade, collect the stragglers, and keep off the wolves, which regularly follow at a distance and migrate with the flock. A few asses or mules carry the clothing and other necessaries of the shepherds and the materials for the fold at night. Several of the sheep are perfectly tamed, and taught to obey the signals of the shepherds. These follow the leading shepherd; for there is no driving, and the rest quietly follow them. The flocks travel through the cultivated country at the rate of eighteen or twenty miles a day; but in open country, with

* Youatt.

good pasture, more leisurely. Much damage is done to the country over which these immense flocks are passing; the free sheep-walk, which the landed proprietors are forced to keep open, interferes with inclosure and good husbandry: the commons also are so completely eaten down that the sheep of the neighbourhood are for a time half starved.

The sheep know as well as the shepherds when the procession has arrived at the end of its journey. In April their migratory instinct renders them restless, and if not guided they set forth unattended to the cooler hills. In spite of the vigilance of the shepherds, great numbers often escape. If not destroyed by the wolves there is no danger of losing these stragglers, for they are found on their old pasture quietly waiting the arrival of their companions.

It is during this journey that the sheep are shorn, and the shearing time is an epoch of primitive oriental festivity. Buildings are erected at various places in the early portion of their journey: they are very simply constructed, consisting only of two large rooms, each of which will contain more than a thousand sheep; there is also a narrow, low, long hut adjoining, called the *sweating-house.* The sheep are all driven into one of these apartments, and in the evening those intended to be shorn on the following day are transferred into the hut. As many are forced into it as it will possibly hold, and there they are left during the night. In consequence of this close confinement they are thrown into a state of great perspiration; the hardened yolk is melted, and thus the whole fleece, by being rendered softer, is more easily cut. There is no previous washing nor any other preparation for the shearing. From 150 to 200 shearers are generally collected at each house, and a flock of a thousand sheep is disposed of in a day. The sheep are turned back as they are shorn into the second apartment, and on the same or the following day continue their journey. Thus in the space of six days, as many flocks,

each consisting of a thousand sheep, pass through the hands of the shearers. The wool is then washed and sorted, and is ready for sale. The rams give most wool: three fleeces often averaging twenty-five pounds.

When the sheep arrive at their summer pasture, salt is placed on flat stones, at the rate of about a hundred weight for every hundred sheep; this they lick eagerly, and it improves their appetite. They are always on the move in search of grass, which is scarce, for they will not touch thyme, which is abundant, and is left to the wild bee. They are never fed until the dew is dry, nor allowed to drink after hailstorms. In September the flocks are daubed with a red earth, which is said to conduce to the fineness of the wool. After their return in October the yeaning time approaches. The Merinos are not good nurses, so that nearly half the lambs, and in bad seasons, when the pasture fails, full three-fourths, are killed as soon as they are yeaned. The skins are sent to Portugal, and from thence to England, where they are used in the glove manufacture. The wool is soft and silky, and is formed in little rings or curls.

March is a very busy month with the shepherds, who then cut off the tails of the lambs and the tips of the horns, that they may not hurt each other in their frolics; the shepherds also mark them on the nose with a hot iron.

Forty or fifty thousand shepherds are said to be employed in tending these sheep. They are a singular race of men, almost as simple as their sheep. Their talk is almost entirely confined to rams and ewes; they know every one of the sheep, and the sheep know them. They live chiefly on bread seasoned with oil or grease, and though they sometimes procure mutton from their old or diseased sheep, it is not their favourite food. Their dress is a jacket and breeches of black sheep-skin; a red silken sash tied round the waist; long leathern gaiters; a slouched hat; a staff tipped with iron, and a *manta,* or brown blanket,

slung over the left shoulder. When they have reached their journey's end, they build themselves rude huts, living generally a single life.

The wool of Saxony owes its celebrity to the introduction of Merino sheep into that country in the year 1765. The Elector of Saxony employed this as one of the means of repairing the devastation occasioned in his dominions by a seven years' war. With the permission of the King of Spain, one hundred Merino rams and two hundred ewes were selected from the best flocks of Spain, and the Elector placed one portion of them on one of his own farms in the neighbourhood of Dresden, and kept them unmixed; and the other portion he distributed on other farms for the purpose of improving the breed of Saxon sheep. It was found after ten years that the wool of the first portion had not degenerated; that, in fact, it was in no way inferior to the choicest fleeces of Leon. The best breed of the native Saxons had also been materially improved. But the prejudices of the sheepmasters led them to refuse to have anything to do with Spanish sheep. The Elector, however, determined to accomplish his object, compelled those who occupied lands under him to purchase a certain number of Merino sheep. This harsh proceeding was however tempered by milder and more salutary measures: agricultural schools and minor schools for shepherds were established, and books containing valuable information as to the treatment of the sheep were largely distributed. The effect of all this was gratifying: the pure Merino breed rapidly increased in Saxony, and not only became perfectly naturalized, but after a lapse of years the fleece of the Saxon sheep exceeded that of the Spanish in fineness and in manufacturing value.

Although the sheep in Saxony are housed at the beginning of winter, yet they are turned out whenever the weather will permit, to seek a portion of their food buried perhaps beneath the snow; and the

season must be unusually inclement in which they are not driven out into the yards for two or three hours during the middle of the day. The doors and windows of the sheep houses are also frequently opened for proper ventilation. Some sheep-masters keep their flock in the house, or in the yard, during the whole of the year; and it is not believed that the animals suffer from this either in health or fineness of fleece. A large quantity of salt is usually given to the sheep, but principally during summer.

When the lambs are weaned, each in its turn is placed upon a table, and its wool and form minutely observed. The finest are selected for breeding, and receive a *first* mark. When one year old, and before shearing time, another close examination of those previously marked takes place. Those in which no defect can be found receive a *second* mark, and the rest are condemned. A few months afterwards, a third and last scrutiny is made; the prime rams and ewes receive a *third* and final mark; but the slightest blemish is sufficient to cause the rejection of the animal. Each breeder of note has a seal or mark secured to the neck of his sheep, to detach or forge which is severely punishable by law.

In France the growth of wool has never been very successfully carried on, the prejudices of the agriculturists being too inveterate to admit of improvement. The breeds of sheep in that country are exceedingly numerous; but, except towards the very south, the character of the wools is still that of being long and coarse. Merinos have been introduced at different times, but not with any decided improvement to the national stock. From the result of careful experiments begun by Daubenton in 1776, and continued for seven years, the conclusion was drawn that the Spanish sheep in other countries, and under modes of management different from those to which they had been accustomed in their native clime, retain every valuable quality for which they are so justly

celebrated. Recent attempts have been made to naturalize English sheep (the improved Leicesters) with apparent success.

Sweden, Denmark, Prussia, and other countries, have all improved their native breeds of sheep by the introduction of Merinos. In Hungary, the chief wealth of which is now derived from the cultivation of the sheep, the flocks were, at one time, among the most wretched and badly managed in Europe. Their milk was the principal, and, in many cases, the only object,—the manufacture of butter and cheese from this product of the sheep being thought more valuable than the application of the fleece to the manufacture of cloth. The Empress Maria Theresa introduced a flock of Merinos; but the prejudices of the sheep-masters against them, could not be overcome, and the good intentions of the empress failed: her example however remained, and was followed, in course of time, by some proprietors; and at length the experiment of improving the native breed by the introduction of Merinos was so successful, that, at the present time, the Hungarian fleece, if not quite so highly valued as that of Silesia and Saxony, has not only rivalled, but beaten the Spanish Merino in every market. Some years ago the sheep of Hungary numbered seven millions, of which three millions were the exclusive property of Prince Esterhazy. When this prince was in England, one of our great agriculturists showed him, with some little pride, his flock of two thousand sheep, and was greatly astonished on learning that the prince had as many shepherds. By a reckoning made on the spot, with one well acquainted with his affairs, it was found that Prince Esterhazy had upwards of two thousand five hundred shepherds.

England was late in attempting to naturalize the Spanish sheep, or to improve her own breeds by an intermixture with them.

In the year 1787, George III. received a small flock of Merinos, collected on the borders of Portugal

from different proprietors and various districts. Consequently there was no uniformity about them, and they did not exhibit the true characteristics of their breed; no experiment was therefore made with them. Whereupon direct application was made to the King of Spain, for permission to select some sheep from one of the best flocks. Permission was readily granted, and a little flock was chosen of the Negrette breed, the most valuable of the migratory flocks, the export of which was expressly prohibited by law. They arrived in England in 1791, and were immediately transferred to Kew.

In this, as in other cases, the experiments were perfectly successful. After a few crossings on the Wiltshires, the ewes became hornless; they had acquired the almost perfect shape of the Merino; the wool had increased from three pounds and a half to nearly six pounds per fleece, and was little inferior to that from pure Spanish sheep.

But prejudice was as strong in England as elsewhere. It was thirteen years after the arrival of the Negrette flock before they had made anything like a favourable impression on our agriculturists; by degrees they were regarded with favour, and at last with enthusiasm. At a public sale of Merinos in 1810, a Negrette ram sold for 173 guineas. A Merino Society was instituted, the president of which was Sir Joseph Banks. Fifty-four vice-presidents were appointed, and local committees established in every county of the three kingdoms; premiums were offered for fine specimens of the Merino breed; but all this was of no avail; the Merino mania yielded to a more powerful force even than prejudice—namely, the interests of the agriculturist. The system of artificial feeding already alluded to, enabled the farmer to send his sheep to market within a very short space of time; and it was found that the Merinos fattened slowly, and were consequently long in arriving at maturity. The increased value of the

wool could not be set against this disadvantage, for the finer foreign wool could be purchased at a cheaper rate than it could be grown. Hence it appeared to be bad policy in the farmer to alter materially the character of his wool, and thus the system which had been adopted with so much success in other countries may be said to have failed in this.

The introduction of the sheep into Australia, affords an instructive example of the increase of a country's wealth by this useful animal. New South Wales had no sheep of its own, but a number were procured from Bengal to provide the colonists with mutton and wool, and to establish a permanent flock. These sheep are described as being more like goats than sheep, the fleece coarse and hairy; but the climate agreed with them, and they are the ancestors of all the improved flocks now in the colony. They were greatly improved by the introduction of the South

THE SOUTHDOWN SHEEP.

Down, and Leicester varieties, and in a short time both the fleece and the carcase doubled in value; but

as the colonists bred chiefly for the sake of the carcase, no particular attention was bestowed on the improvement of the wool. In 1800 there were only 6124 sheep in the whole settlement; but about this time Merinos had begun to gain a footing in England. A few were imported from England, and the experiment of improving the sheep of the colony with them was so successful, that in a short time the fleece of the mixed breed was equal to that of the pure Merinos in Europe, and the wool of the pure breed improved rapidly. The number of sheep rapidly increased. Within the next three years it had risen to 10,157; in 1813, to 65,121; in 1817, to 170,420; and in 1828, to 536,391.

The breed was still further improved by Captain John Macarthur, who supposed that if the fleece of the common Merino sheep became finer and softer in the soil and under the climate of New South Wales, it was not improbable that even the Saxony wool might somewhat increase in value. He, therefore, imported some sheep direct from Germany, and after the experiment had been fairly tried, it was found that if the Saxon fleece were not improved, its properties were superior to any that the colony had hitherto possessed. Mr. Hughes, a Blackwell-hall factor, in his evidence before the House of Lords, speaks of Australian wool generally, and of this wool in particular, in the following terms:

"The qualities of the wool were originally very bad. Latterly they have been of varied qualities, but they all possess an extraordinary softness, which the manufacturers here so much admire, and they are sought for more than any other description of wools. I should conceive that that country is adequate to the growth of as much wool of a fine description as will ever be wanted by the manufacturers of England. This wool would also mix beautifully with our own wools, which other foreign wools do not always, on account of the harshness of the fibre."

"There is no other wool which spins so well as the Australian, from its length of staple and peculiar softness. The finer description of stuff which is now so much manufactured, is made of this wool. Whether from the climate, or the herbage, or both, the wool has improved in softness and in staple too; and I have no doubt that we shall shortly derive the whole of our supplies of foreign wool from that part of the globe." Mr. Donaldson, a wool merchant, says that the Australian wools "have a softness and silkiness about them, which, when worked into cloth, shows itself more distinctly than in the raw material of the same description."

The success of the Australian wool, however, may be seen in the following table, shewing the imports of wool into this country:

In 1810	167 lbs.
1820	100,000
1831	1,134,134
1833*	3,516,869
1839†	10,128,774
1840‡	9,721,243
1841	12,399,090
1842	12,979,524
1843	17,433,732

The influence of the Australian wool in our markets may, to a certain extent, be judged of from the fact, that in 1836, Germany supplied us with 31,766,194 lbs. of wool; and in 1843, with only about half that quantity, namely 16,805,448 lbs.

THE MANUFACTURE OF WOOLLEN YARN.

The manufacture of articles from wool admits of two grand divisions, which in practice are perfectly separate and distinct from each other: these divisions

* This includes New South Wales and Van Diemen's Land.
† Swan River is here included in the former settlements.
‡ Including also South Australia.

are, the *short wool* or *cloth* manufacture, and the *long wool* or *worsted* manufacture. In the former advantage is taken of that peculiar property of wool called *felting*. The yarn being softly and loosely spun, and the woollen fabric woven, it is submitted to heat, moisture, and pressure, by which the fibres become so matted together, as to form an almost uniform mass. This felting property is, however, neglected in the case of worsted; the long wool is combed out, the fibres are stretched and laid even, and the thread is twisted, and spun hard, so as to feel close and thread-like to the touch, and not soft and loose like the yarn intended for woollen cloth, the preparation of which yarn will first be noticed.

The writer's information on this subject has been greatly assisted by a visit to the mill of Messrs. John Brooke and Sons, of Armitage Bridge, near Huddersfield, who kindly allowed drawings to be made from their machinery. Many beautiful processes, and ingenious machines, witnessed at this mill, will be described in a subsequent treatise on the manufacture of woven goods; the present object being to trace the wool merely up to the state of yarn.

SORTING.

The bales of wool having been unpacked, the fleeces are opened and sorted; they are first beaten with wooden rollers to get rid of dust and to facilitate the opening of the fleece; then commences the wool-sorting, a process which requires great skill, delicacy of touch, and constant practice; so much so, that the services of a wool-sorter are said to be impaired if he remains out of practice even for a few weeks. The sorter opens the fleece upon the floor and then takes it to a table or horizontal frame-work of bars of wood, between which loose dirt, or foreign substances escape. As it is clearly impossible to make one uniform quality of cloth from different qualities of wool, the sorter

separates the fleece into several portions, according to their fineness of fibre, softness, soundness of the staple, colour, cleanliness, and weight.

The fineness of the fibre is of very great importance, since it is evident that no art can convert a coarse wool into a fine, compact, and even cloth. The wool from different parts of the same animal differs greatly in fineness; some wool being fine only at the lower end, near the back of the animal, while that from the other parts is coarse and hairy. Wool is always more or less irregular, with respect to fineness, that of the Merino sheep being remarkable for evenness or regularity; and even the finest Merino fleece is usually divided into four qualities, the first three being called by the Spaniards, *refina*, *fina*, and *tercera*; the fourth or coarse part, from the head and shanks, being seldom sent to market. In English fleeces the finest portion seldom exceeds one-third, but our sorters make eight or ten divisions or sorts out of the whole fleece: these are called *prime*, *choice*, *super*, *head*, *downrights*, *seconds*, *fine abb*, *coarse abb*, *livery*, *short coarse* or *breech wool*. Some sorters will select from the prime sort a few remarkably fine locks, so as to produce a very superior sort, called *pick-lock*.

It has been ascertained by microscopic examination that the finest wools are about 1-1500th of an inch in diameter, and the coarsest of the long or combing wools about 1-450th of an inch in diameter; but it is said that a skilful wool-sorter will detect differences which are not appreciable by the microscope.

The *softness* of the fleece is as important a quality as fineness, the felting property depending in great measure upon it. Saxony wool is celebrated for its softness; but the wool most distinguished in this respect is produced in India by a small variety of sheep; it grows very near the skin, with long coarse wool or hair growing through it.

The *soundness* or strength of staple is of less importance in clothing wool than in combing wool, but,

nevertheless, of great consequence, as the durability of the surface of the cloth depends on it.

The whiteness of the wool is called its *colour*, and this is of some importance to the success of the dyeing process: it is, of course, necessary for light and bright colours, and the darkest colours are said to be richer and more lustrous on a clear white ground than a dark or mixed wool. Wool is apt to get heated and discoloured, from being packed too close.

As the quality of the wool becomes deteriorated by the presence of the yolk, the sorter judges of the *cleanness* of the fleece, by the presence or absence of this substance; and this also determines, to a certain extent, its weight, which ought not to arise from the presence of yolk, but from the closeness of the pile, a quality, which usually accompanies softness and shortness of staple.

The sorter disposes of the various sorts or qualities of wool in large baskets, and then weighs them, and makes them up into what are called sheets, preparatory to dyeing.

SCOURING, DYEING, WILLOWING AND OILING.

The wool being sorted, sheets of the same quality are collected together, and scoured or washed, to get rid of the animal grease. This is done in the dye-house, which forms an extensive shed, detached from the mill. The wool is soaked in stale urine, mixed sometimes with a small quantity of soap, and heated to about 120°. It is next put into wire baskets, and submitted to the action of running water, which washes away the grease and other impurities. In the washing of long, or worsted wool, the offensive ingredient in this process is dispensed with; the wool is cleansed in warm soap and water, then washed in clear water to get rid

of the soap, and lastly pressed dry between strong iron rollers.

The wool is now fit for dyeing. A distinction is made between cloth that is *wool-dyed* and *piece-dyed*. In the one case, the dyeing is performed at this stage; and in the other, it is deferred until after the yarn is spun and the cloth woven.

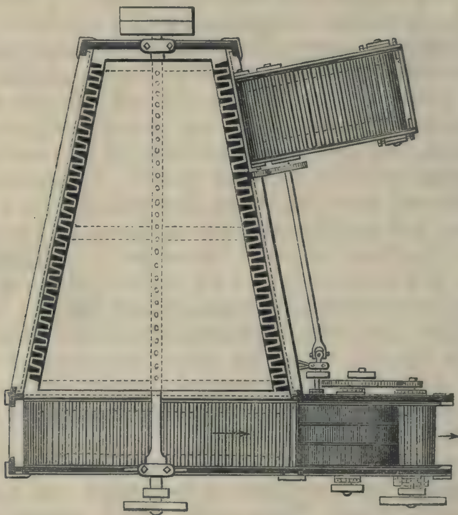
The dye-house is furnished with a number of large coppers or vats, containing the colouring matter in which in the case of blue dyeing the wool is boiled. The wool is put into a net, and pressed down into the liquor. After boiling a sufficient time, it is taken out, and as much of the liquor pressed out as is possible, by twisting the net round and round. When the wool is removed from the indigo blue vat, it is of a green colour, but speedily changes to blue, by absorption of oxygen from the air. The subject of dyeing, however, is too extensive to be considered here; it is, therefore, reserved, for a subsequent treatise.

When the wool is properly dyed, it is spread out in the drying house for about twenty-four hours, on racks to dry; it is then again made up into sheets, in order that the sorts or qualities, determined by the sorter, may be recognised.

The wool is then passed through the *willy*, or *shakewilly*, as it is called in Yorkshire, and *twilly* in Gloucestershire. These terms are a corruption of the *willow* of the cotton manufacture, and this again is probably a corruption of *winnow*, the action of the machine being to winnow the wool of twigs, dust, dirt, stones, and other impurities.* There are many forms of willow, but the most approved consists of a cone armed with four rows of iron spikes, revolving from three to five hundred times a minute. This cone is surrounded by a case, within which are similar spikes, placed so as to alternate with the spikes on the cone. The wool being spread on a travelling

* According to some authorities the first willowing machine was made of *willow* wood, and hence the name.

apron at the smaller end, is conveyed into the case, where it is seized by the spikes, torn, disentangled, and cleansed, the heavier impurities falling through the perforated bottom of the machine; then, by the gradually increasing centrifugal force, the wool is im-



pelled forwards to the large end, where it is thrown into a chamber and conveyed, upon another travelling apron, out of the machine. Over this apron is a cylindrical wire or squirrel cage connected with a revolving fan, which draws the dust out of the chamber, through a chimney or pipe, while the cage prevents the fibres of wool from being wafted away with the dust. This cage is made to revolve over, and press upon the apron, by which means it lays down the wool in a continuous fleece. Some of the coarser wools are willied before as well as after dyeing.

The wool is next spread out upon a stone floor, and

oil is poured upon it, from a kind of watering pot, three or four pounds of Gallipoli oil being intimately mixed with about twenty pounds of wool. The wool is once more willied, in order to incorporate the oil thoroughly with the woollen fibres.

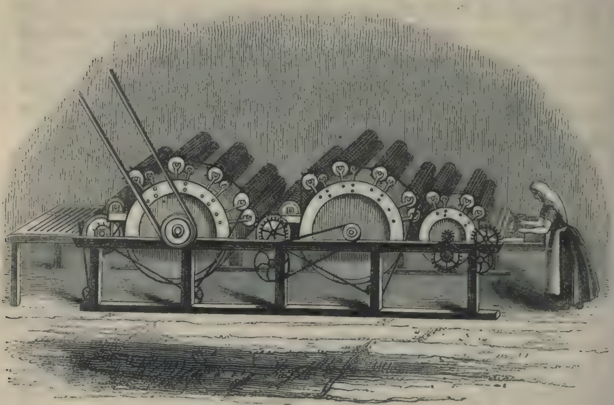
The manufacturer then weighs out and mixes various sorts together, according to the quality of cloth intended to be woven, the willy being once more used to blend the different sorts together. The wool is now ready for scribbling.

SCRIBBLING AND CARDING.

Scribbling scarcely differs from the process of carding, which was described somewhat fully in the treatise on the "Manufacture of Cotton Yarn." Scribbling, however, is a coarser process, and the machine forms the oiled wool into a broad thin fleece, or lap, the fibres of which are opened and separated. The wool goes through the scribbler always twice, sometimes three or four times, so that the fibres may be completely disentangled and separated. It is carded only once.

The wool-carding engine differs, in some particulars, from the cotton carding engine. The fibres of the wool are more twisted, elastic, and stiff, than those of cotton, and require the carding apparatus to be so arranged, as not only to open the wool without breaking it to pieces, but also to make the fibres cross each other in every possible direction. The wool-carding engine consists of large cylinders or card-drums, surmounted by smaller cylinders called *urchins,* all covered with carding wires. The smaller cylinders, which are arranged in pairs, are of unequal size; the larger of the two is called the *worker*, and the smaller the *cleaner:* these revolve at great speed. At one end of the engine is an endless feeding cloth, upon a certain length of which a given weight of the oiled

wool is spread evenly by hand. This delivers the wool through a pair of feeding rollers, which distribute it on the card drum. From this the wool is



WOOL-CARDING ENGINE

gradually stripped by the first worker, whence it is received by the first cleaner, and by it again deposited in the large card drum. When it has passed over the last cylinder into the drum, it is taken from it by a doffing cylinder, from which the wool is removed by a steel comb, or doffing knife, moving rapidly up and down. The doffing cylinder is not entirely covered with wires, but merely with a succession of card leathers, arranged in straight bands, parallel to its axis, with spaces between every two bands. The effect of this arrangement is, that the doffing knife removes the wool in the form of separate slivers, each the length of the doffing cylinder, and these, instead of being wound upon a roller, fall into the plates of a plated cylinder, called the *roller-bowl*, which, being partly covered with a case or shell nearly in contact with it, the slivers are rolled into cardings, and are received upon an apron at the op-

posite end of the machine. The cardings are weighed from time to time, to see that each contains the proper quantity of wool.

Carding was formerly done by hand, with flat hand or stock cards; but the workman, carding always in the same direction, was not able sufficiently to intermingle the fibres, so that the wool was deprived of much of its felting property, and the yarn spun from it was consequently weakened.

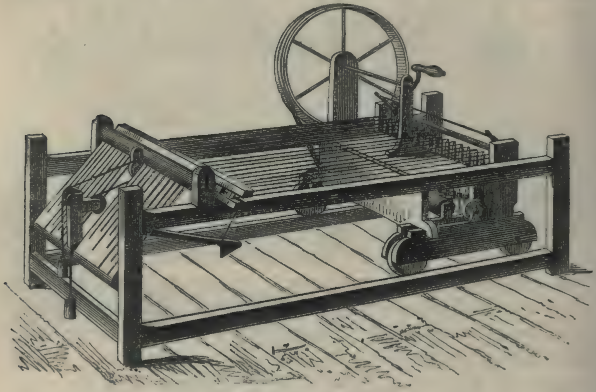
SLUBBING.

Some time after the introduction into the cotton manufacture of the Spinning Jenny, (the history and description of which have already been given,) an attempt was made to employ a similar machine in the preparation of woollen rovings, or *slubbings* as they are called, and which, from time immemorial, had been produced by hand on the spinning wheel. The attempt succeeded, and the machine, under the name of the *Slubbing-Billy,* continues still in use, for preparing the slubbings which are afterwards to be spun by the mule.

The Slubbing Billy consists of a wooden frame, within which is a carriage capable of being moved upon the lower side rails, through a space of several feet called the *billy-gate,* from one end of the frame to the other. This carriage contains a number of spindles, which are made to rotate rapidly by a series of cords passing round the pulley of each spindle, and connected with a drum extending the whole breadth of the carriage, to which motion is given by the slubber turning the handle of the large wheel, which is connected by a strap with the drum.

The cardings are arranged upon a leathern or hempen apron, which is mounted, in a slanting direction, at the end of the frame, opposite to the moveable carriage. These cardings pass under a wooden roller, called the

billy roller, which presses lightly upon them so as slightly to compress them. In front of this roller is a moveable rail, which, when it rests upon the cardings, prevents them from being drawn through, and, when elevated, prevents the cardings from being drawn forward by the retiring of the spindle carriage.



THE SLUBBING BILLY.

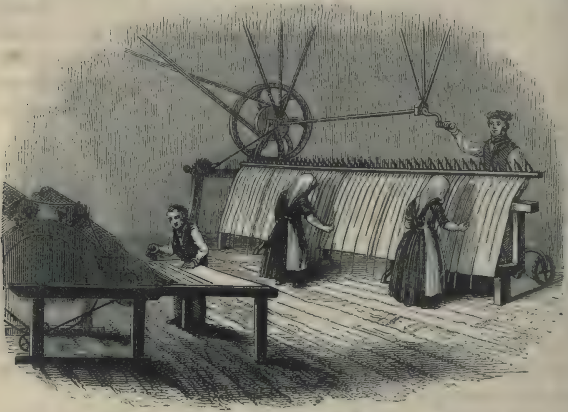
When the spindle carriage is wheeled close up to the billy roller, the clasp is opened by means of a lever, so as to release all the cardings. The carriage being then drawn a short distance from the clasp, pulls forward a corresponding length of the cardings; the clasp then falls down and holds the cardings firmly, while the carriage continuing to recede, draws out and stretches that portion of the cardings which is between the clasp and the spindles. During this time the slubber keeps turning the wheel which causes the spindles to revolve, thus giving the cardings the proper degree of twist. This twist does not form yarn, for the slubbing has to be twisted in the contrary direction, when it is afterwards spun at the mule. Slubbings intended for warp yarn, must be more twisted than those for weft.

The inclined direction of the spindles gives to the cardings, or rovings, as they may now be called, a twisting motion, whereby they are continually slipping over the points of the spindles without getting wound upon them. When the rovings are properly twisted, the slubber winds them upon the spindles, by pressing down a faller-wire, so as to bear down the rovings from the points of the spindles, and place them opposite their middle part. He then makes the spindles revolve while he slowly pushes in the carriage, so as to wind the rovings upon the spindles in the form of conical cops.

The cardings are so tender, that, if allowed to be dragged over the endless apron, they would be liable to break. The rollers upon which the apron is stretched, are, therefore, made to revolve by means of two unequal weights attached to them by cords. When the carriage is pushed home, the heavier weight gets wound up; and, when the carriage is drawn out, this weight turns the roller and advances the endless apron, so as to deliver the cardings at the same rate as the carriage runs out.

The cardings are brought from the carding engines by children, who lay them over the left arm, and, by a slight lateral rolling motion of the fingers of the right hand, not easy to describe, join them on to the ends of the cardings on the apron. This is repeated as often as necessary, and, to prevent the improper thickening of the cardings at the juncture, each carding is smaller at the ends. Some little tact is required by the children to prevent any inequalities. They must be careful not to stretch the cardings in lifting them up, and must join them evenly and effectually. Unless these points are attended to, the slubbings form what are called "flies," or "ratched cardings." Unless all the ends are joined by the time the former cardings are drawn through, the ends are said to be "let up," and when this happens the work is considerably delayed.

It is surprising to notice the rapidity with which the piecening is performed; the fingers of the children become polished in a singular way by the constant handling of the oiled wool. In the Messrs. Brookes' mill, the children had a cheerful and healthy appearance,



MODERN SLUBBING MACHINE.

although the face was often seen smiling through a mask of indigo blue, and the hands and arms were stained with the same substance. "Children are preferable as pieceners, not simply from the cheapness of their labour, and the mobility of their muscles, but from their size, as they can work without constraint at the billy-board, which must be kept low for the convenience of the slubber, and could not be properly served by taller persons without painful and injurious stooping."

It is usually calculated that one carding engine will keep one billy with sixty spindles in active employment. One slubber should have two pieceners, so that each child has thirty cardings to manage.

SPINNING.

The wool is now in a fit state to be spun into yarn, proper for the manufacture of woollen cloth. The process of spinning does not differ from that of Cotton Mule Spinning, and, therefore, need not be described again.

THE MANUFACTURE OF WORSTED YARN.

The preparation of worsted yarn closely resembles that of cotton, and is essentially different from that of short wool or clothing yarn; for while, in the latter, the fibres are entangled and crossed in every possible direction, in order to assist the felting property, care is taken in the preparation of the former to dispose all the fibres as nearly as possible in parallel lines.

When the long wool is received at the factory, it is washed in soap and water. Much of the moisture is pressed out by rollers, after which the wool is conveyed in large baskets to the drying-room, where it is spread over the floor. The drying-room is usually situated immediately over the boiler of the steam-engine, and is thus economically heated.

When the wool is dry, it is removed to a kind of willowing machine, called the *plucker*. This is attended by a boy, whose business it is to spread the wool, with tolerable regularity, over a feeding apron, which, by advancing, delivers the tufts of wool to a pair of fluted rollers, which convey it to a fanning apparatus.

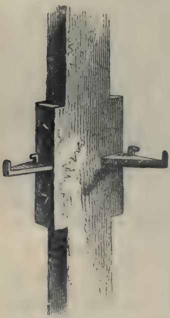
After the wool has passed through this machine, it is ready for combing. For the finer descriptions of long wool, this is still done by hand. It is a laborious and unhealthy occupation, being carried on in rooms which feel oppressively hot to a casual visitor.

The wool-comber employs three implements, namely, a pair of *combs*, a *post* to which one of the

combs can be fixed, and a small stove, called a *comb-pot,* for heating the teeth of the combs.

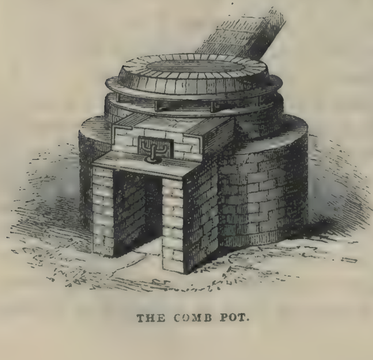
LONG WOOL-COMB.

The wool-comb is composed of two or three rows of pointed, tapering, steel teeth, the rows being of different lengths. They are fixed to a wooden stock or head which is covered with horn, and from this head proceeds a perforated handle, made to fit into certain projections in an upright post, upon which the combs are occasionally rested during the operation. The turned-up part of the iron stem enters a hole in the handle of the comb, while the staple near the post enters the hollow end of the handle, thus holding the comb secure.



COMB-POST.

The comb-pot consists of a flat iron plate, heated by fire or steam, and above this is a similar plate, with sufficient space between the two to admit the teeth of the comb.



THE COMB POT.

The heated comb being fastened to the post with the teeth upwards, the workman takes a handful of wool, sprinkles it over with oil, rolls it up in his hands to distribute the oil uniformly, and then throws about one-

half of the wool over the points of the comb, drawing it through them repeatedly, leaving each time a few straight filaments in the comb. When the handful of oiled wool is thus disposed on the comb, the comb is removed to the stove, so as to expose the wool to the influence of the heat. An empty comb is at the same time taken from the stove and mounted on the post, where it is filled with wool as before. He then takes the two combs, and, sitting down upon a low stool, holds one of them with his left hand over his knee, and, holding the other in his right hand, introduces the teeth of one comb into the wool stuck in the other, and draws them through it; by which operation the wool is transferred to one comb. This process is continually repeated, until the fibres are laid truly parallel. The man begins by combing out the ends of the wool, advancing gradually from one end to the other, until at length the teeth of the combs are very near together. About one-eighth of the wool remains on the teeth of the comb after each operation; and this quantity, which is called *noyl*, being too short for the comber to grasp in his hand, is transferred to the short wool manufacturer. The wool, after it has left the comb, requires to be combed again, at a lower temperature, before it is fit for the spinner.

Many attempts have been made to supersede this laborious and unhealthy operation by self-acting machines. One of these, as seen by the writer at Halifax, consisted of two large wheels, ten feet in diameter, set nearly upright, the comb-teeth forming a circle round the rim of each wheel, at right angles to its plane, the points of the comb in the two wheels being turned towards each other. The wheels are furnished with hollow iron spokes, filled with steam, for the purpose of maintaining a proper combing heat. A boy, seated on the ground, strikes the wool in handfuls upon one wheel, which is made to revolve slowly for the purpose. The wheel is then made to

revolve more rapidly, and the teeth of one wheel, sweeping obliquely over the teeth of the other, smoothe out the tangled locks with great delicacy and precision. "When the wools are set in rapid motion, the loose ends of the fleece, by the centrifugal force, are thrown out, in the direction of radii, upon the teeth of the other revolving comb-wheel, so as to be drawn out and made truly straight. The operation commences upon the tips of the tresses, where the wheels, by the oblique posture of their shafts, are at the greatest distance apart; but, as the planes slowly approach to parallelism, the teeth enter more deeply into the wool, till they progressively comb the whole length of its fibres. The machines being then thrown out of gear, the teeth are stripped of the tresses by the hand of the attendant; the *noyls*, or short refuse wool, being also removed, and kept by itself."

BREAKING, DRAWING, AND SPINNING.

The wool, as it is combed into slivers, is formed into narrow bundles, called *tops*, each containing about a pound and a half or two pounds. These being unrolled, the slivers are separated and thrown loosely over a pin, within reach of the attendant, who takes a sliver, spreads it flat upon an endless felt or feeding board, presenting the end to the first pair of rollers of the *sliver-box* or *breaking-frame*, which draw the sliver in. When it has passed half through, the end of another sliver is placed upon the middle of the first, and they are drawn through together. Care is taken to splice the long end of one sliver to the short end of another. When this second sliver has passed half-way through, the end of a third is placed on the middle of it, and in this way the short slivers

are united and extended by other pairs of rollers into one long and uniform sliver, eight times the length which it had on the feeding-board.

BREAKING-FRAME.

The slivers from this machine are received into cans, eight of which are drawn into one at the drawing-frame. These are also received into cans, and being again drawn out and slightly twisted are wound upon bobbins. At about the fifth drawing, a number of yards are weighed, so as to ensure a given length to a given weight of yarn. If the sliver is not of the length required for the size of the worsted intended to be spun, the speed of the drawing frames is changed accordingly. At the time of the writer's visit to Messrs. Ackroyd's extensive factory at Halifax, the doubling and drawing were performed at seven or eight frames, so as to ensure great uniformity and fineness of yarn. The roving and spinning so closely resemble those processes in the cotton manufacture as to require no further description in this place.

DRAWING-FRAME.

STATISTICS.

The localities of the woollen and worsted manufactures were originally determined in a great measure by the facility of procuring the raw material, and the existence of falls of water for working the machinery. Many of the places where the woollen manufacture was once thriving are now no longer manufacturing districts, a change produced, to a great extent, by our altered system of conveyance. Previous to the reign of George III. the state of the roads throughout the kingdom rendered it difficult to convey bulky or heavy articles from place to place. Wheeled carriages could be little used, and *pack* horses were so general a means of conveyance, that they even took their names from their customary burden—*packs* of wool. With this tedious and expensive mode of conveyance,

the manufacturer would be likely to settle as near as possible to those districts where the wool was grown, and where he could find a sale for his goods at no great distance from his dwelling. The nature of his fabric would also be decided by the quality of the wool produced in his neighbourhood. Under these circumstances, a large number of small manufacturers would be scattered over the country, each master giving employment to his neighbours and their families who had spinning-wheels and looms in their cottages, while the children and servants worked under his own direction.

On the improvement of roads and the introduction of canals the woollen manufacturers gradually removed to the South of Lancashire and the West Riding of Yorkshire, where, by means of canals, there was a cheap and ready access to Liverpool and Hull,—seaports which supplied the raw material from distant parts of the island, as well as from all parts of the world, and, at the same time, opened markets both domestic and foreign, for disposing of the manufactured goods. The natural riches of Yorkshire and Lancashire assisted greatly in locating the woollen manufacture: waterfalls, coal, iron, and limestone, offering remarkable facilities for the construction of machinery. This part of our island may indeed be regarded as the birth-place of the spinning-machine and the steam-engine.

For a long period the coarse woollen manufacture was, with few exceptions, concentrated in Yorkshire, and the borders of Lancashire; while the manufacture of fine cloth, originally established where the finest English wools were produced, remained in Gloucestershire, Wiltshire, and Somersetshire, having the advantage of Bristol as a sea-port. When the merchants of Bristol brought from Spain and Portugal the fine wools of those countries, the finest qualities of cloth were manufactured in the counties just named. The manufacturers sent their goods to

the Blackwell-hall factors in London, from whence they were sold and distributed over the whole kingdom.

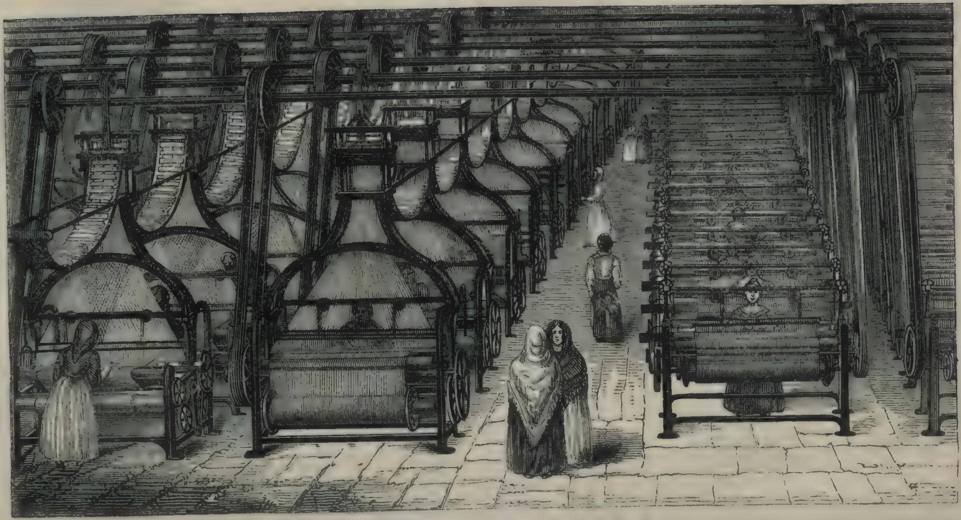
The introduction of Merino sheep into the North of Europe, and the great and increasing production of the finest wools there, (at first rivalling, and then surpassing those of Spain,) together with increasing facility of communication, soon enabled Yorkshire, with its many natural advantages, to compete with the West of England, with such success as to nearly ruin her trade. The manufacture of the finest fabrics has been transferred to Yorkshire, where, together with that of the coarser article, it is likely to continue.

The quantity of wool imported into the United Kingdom in the year 1843, amounted to 49,243,093 lbs., and in 1844, to 65,713,761 lbs. Of the quantity supplied in 1843, the British possessions contributed 21,132,352 lbs.; Germany, 16,805,448 lbs.; Russia, 3,511,916 lbs.; Peru, 2,535,200 lbs.; the States of the Rio de la Plata, 1,879,653 lbs.; Spain, 597,091 lbs.; Portugal, 475,423 lbs.; Turkey, Syria, and Egypt, 508,205 lbs.; Italy, 231,113 lbs.; the United States of America, 126,615 lbs.; Morocco, 81,788 lbs.

In 1843, British wool was exported to the amount of 8,179,639 lbs., of which Holland and Belgium received 6,302,170 lbs.; France, 1,677,706 lbs.; and the United States of America, 88,983 lbs.

In 1843, of British woollen and worsted yarns were exported, 7,410,313 lbs., of which Germany, Holland, and France, received the largest share.

In the manufacture of woollen and worsted yarns there is no process prejudicial to health. The operatives, old and young, appeared to be in excellent health. The children are educated in well-conducted schools, either attached to the factories, or, as is the case at Armitage Bridge, at a short distance from them.



ACKROYD'S LOOM-SHED AT HALIFAX.—(*Worsted Goods.*)

THE

MANUFACTURE OF WOVEN GOODS.

PART I.

ONE of the earliest arts that appeared among mankind was that of weaving, or interlacing fibrous substances so as to form cloth. It is impossible to refer to any one country in particular for the invention of this art, for, as it has been well observed, "the same wants, and the possession of nearly similar means for their gratification, might naturally lead to a discovery of the method whereby those means could be rendered available."

The art of weaving was probably known before that of spinning; rushes, straws, grasses, and the fibrous parts of plants, would furnish materials for a kind of matting such as is manufactured at the present day by many rude nations. The twisting or spinning of fibrous substances so as to form continuous and unbroken threads seems to belong to a somewhat advanced state of civilization. Indeed, from an expression of the inspired writer, it would seem that the art of spinning required no common skill, for we read (Exodus xxxv. 25,) that "all the women that were *wise hearted* did spin with their hands." Weaving is also one of the arts mentioned by Moses in the chapter just quoted, (verse 35) as being taught by them whom the Almighty had "filled with wisdom of heart to work

all manner of work, of the engraver, and of the cunning workman, and of the embroiderer in blue, in purple, in scarlet, and in fine linen, and of the *weaver*, even of them that do any work and of those that devise cunning work."

Woven cloth is always composed of two distinct threads, or yarns, which traverse the *web* or piece of cloth in opposite directions, and are usually at right angles to each other. Those threads which form the length of the web are called the *warp*, and they extend entirely from one end of the piece to the other. The cross thread or yarn runs across the cloth, and is called the *weft* or *woof*. This is in fact one thread continued through the whole piece of cloth, passing alternately over and under each yarn of the warp, until it arrives at the outside one. It then passes round that yarn, and returns back over and under each thread as before; but in such a manner that it now goes over those yarns which it passed under before, and under those yarns which it previously passed over, thus firmly weaving the warp together.

It is necessary at the outset to form a clear idea of weaving, and to be able to distinguish it from other processes whereby a kind of cloth or textile fabric is produced, as in *paper making*, *felting*, *platting*, *netting*, *knitting*, and *sewing*.

In *paper making* the fibres are neither spun into one thread, nor interlaced, but are crossed in all directions, and combined into one sheet by mere compression and agglutination. *Felting* is similar in some respects to paper making; vegetable fibres, however, are wholly unfit for felt, those of wool and hair being employed. These fibres are crossed in all directions; but, instead of being merely pressed together, and rendered compact by agglutination, the woollen fibres are forcibly rubbed and worked together, so as to be looped and interlaced in every conceivable way, the serrated edges locking into each other so as to form a compact cloth, far more durable

than paper, and capable of resisting rain and moisture. Felting is supposed to be a more ancient art than weaving, the natural tendency of the wool on the sheep's back to felt having probably suggested the art at an early period.

Platting approaches nearer to weaving, because the fibres are regularly interlaced; but they are not previously drawn out or twisted into thread, as is the case in weaving. The South Sea Islanders, and other rude nations from the remotest antiquity have made basket-work, mats, cloaks, sails, and many other articles, by crossing and interlacing long strips of leaves, straws, bark, &c.

Netting is a still nearer approach to weaving, the fibres being previously spun or twisted into threads. In netting, the threads or cords are tied into hard knots where they cross, so that each mesh is incapable of enlargement or diminution.

Knitting is a modern art, said to have been invented in Scotland about the year 1500. It is a mode of weaving adapted to the production of small articles of dress; and the whole of the required apparatus can be attached to the person, or held in the hands of the knitter. The essential distinction between knitting and weaving is, that in the former one thread is employed for both warp and woof; the thread being passed at each stitch, first in the direction of the weft, and then in the direction of the warp, a succession of loops is produced in successive rows, and the loops of each row are drawn through the loops of a former row. This is the principle of stocking knitting, in which the whole fabric consists of one continuous thread.

Sewing has the same general object as weaving, it being used to join together pieces of cloth, felt, skin, or leather, and is also used in mending clothes. One variety of sewing, called *darning*, is a perfect imitation of weaving on a small scale. It is done with a needle and thread, and is the best way of filling up

a hole in any textile fabric, for by this method the threads are arranged just as they are in the cloth, namely, at right angles, and regularly interlaced.

HISTORICAL NOTICES OF WEAVING.

According to Pliny, the Egyptians invented the art of weaving; but from what has been already stated, it is probable that they were only improvers of the art. From many passages in the Holy Scriptures, and other writings, we learn that the Egyptians were celebrated for their woven fabrics at a very early period. The produce of their looms, the fine linen and embroidered work, the yarn and woollen stuffs of the upper and lower country are frequently mentioned, and were highly esteemed. Persia, Babylonia, Phœnicia, Phrygia, and Lydia, are also celebrated for the wonderful skill and magnificence displayed in the manufacture of scarfs, shawls, carpets, and tapestry; and this skill becomes the more surprising when we consider the simple character of the implements employed. Sir J. G. Wilkinson states that the looms depicted on the tombs at Thebes are of a very rude construction; but he does not think that this circumstance is any proof against the production of fine fabrics, since it is known at the present day, with what rude and apparently inadequate apparatus the Hindu produces his exquisite muslins. Indeed, many specimens of ancient Egyptian skill have been singularly preserved to our own day in the mummies of those remarkable people. Mr. Thomson, who is a good authority on this subject says:—

"The beauty of the texture, and peculiarity in the structure of a mummy-cloth, given to me by Mr. Belzoni, was very striking. It was free from gum, or resin, or impregnation of any kind, and had evidently been originally white. It was close and

firm, yet very elastic. The yarn of both warp and woof was remarkably even and well spun. The thread of the warp was *double*, consisting of two fine threads twisted together; the woof was single. The warp contained ninety threads in an inch; the woof, or weft, only forty-four. The fineness of these materials, estimated after the manner of cotton yarn, was about thirty hanks in the pound.

"The subsequent examination of a great variety of mummy-cloths showed, that the disparity between the warp and woof belonged to the system of manufacture, and that the warp generally had twice or thrice, and not seldom four times, the number of threads in an inch that the woof had; thus, a cloth containing eighty threads of warp in the inch, of a fineness about twenty-four hanks to the pound, had forty threads in the woof; another with one hundred and twenty threads of warp, of thirty hanks, had forty; and a third specimen only thirty threads in the woof. These have each respectively double, treble, and quadruple the number of threads in the warp that they have in the woof. This structure, so different from modern cloth, which has the proportions nearly equal, originated, probably, in the difficulty and tediousness of getting in the woof, when the shuttle was thrown by hand, which is the practice in India at the present day; and which, there are weavers still living old enough to remember, was the universal practice in this country."

Some of the finest kinds of mummy-cloth sent to England appeared to be muslin, of Indian manufacture, but on examining them by the microscope, they proved to be linen. Some were thin and transparent, and of very delicate texture. The finest appeared to be made of yarn of near 100 hanks to the pound, with 140 threads in the inch in the warp, and about sixty-four in the weft. Striped goods were often made, and indigo was used as one of the dyes. Some of the ancient looms are horizontal;

others vertical, in which latter case the weft is driven upwards; the shuttles were, probably, about half a yard in length.

Modern Egypt has not retained the celebrity of

MODERN EGYPTIAN WEAVER.

ancient times for its fine linen and other fabrics. The accompanying sketch represents a modern Egyp-

tian loom, which, it will be seen, is a rude and primitive machine. Its most remarkable feature is the disposition of the warp threads, which, according to a very ancient practice, instead of being wound round a roller, as in the European looms, are extended to their whole length; and, for economy of space, passed over a roller near the ceiling, where they are kept stretched by a large stone. When the warp is too short to pass over the upper roller its upper ends are attached to a stick, and this to a cord, which carries the weight over the roller for keeping it stretched.

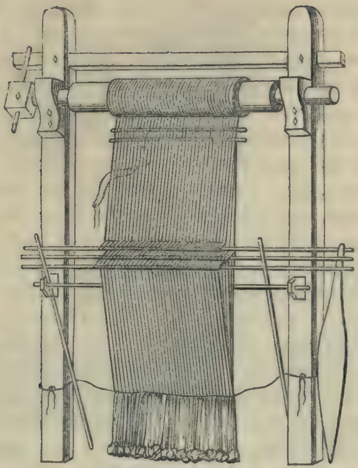
Much valuable information respecting the art of weaving among the Greeks and Romans has been collected by Mr. Yates* from the descriptions of ancient authors, from which it appears that the productions of the loom in ancient times were very little, if at all, below the beauty and variety of the damasks, shawls, and tapestries of the present age, and they vied with the works of the most celebrated painters in representing, first, mythological, and afterwards, Scriptural subjects.

Among the ancient Greeks and Romans, weaving was not only a distinct trade, carried on by a separate class of persons, but every considerable domestic establishment in the country contained a loom, together with the whole apparatus necessary for the working of wool. These occupations were supposed to be carried on under the protection of Minerva, who was always regarded as the friend and patroness of industry, sobriety and female decorum. The work was performed principally by female slaves, under the superintendence of the mistress of the house, who, together with her daughters, also took part in the labour, instructing the beginners, and finishing the

* Smith's *Dictionary of Greek and Roman Antiquities*: article *Tela.* Much valuable information respecting the useful arts among the ancients is also to be found in Mr. Yates's *Textrinum Antiquorum.*

more tasteful and ornamental parts. During the early ages, the art of weaving was principally confined throughout Europe to the female sex. Herodotus mentions it as a peculiarity of Egyptian manners, that the men wove. In the fourth century, weaving began to be generally practised by men, a circumstance deplored by St. Chrysostom, as a sign of prevailing sloth and effeminacy. Some of the more opulent temples, in ancient times, kept an establishment of weavers for supplying the shawls and furniture used in their solemn rites. Thus the sixteen women who lived together in a building destined to their use at Olympia, wove a new shawl every five years, which was displayed at the games celebrated in honour of Hera, and was preserved in her temple. The weaving of shawls used in some of the processions was sometimes assigned to young females of the highest rank.

While the form of the ancient loom has been greatly modified in most parts of Europe, it is supposed to have remained in Iceland almost in its primitive state. The warp, which is suspended in a frame, besides being separated by a transverse rod or plank, is divided into thirty or forty parcels, to each of which a stone is suspended for the purpose of keeping the thread stretched, and allowing the necessary play to the strokes of the spatha, a large wooden sword, still used in Iceland exactly as it was in ancient times, for driving home the weft after it had been conveyed through the warp. The spatha was superseded by the comb, the teeth of which were inserted between the threads of the warp, and thus used to drive the threads of the weft close together. The teeth of the comb were curved, as is still the case in the combs used by the Hindoos. In the modern loom the comb has been superseded by the reed, lay, or batten. The spatha is represented in the accompanying cut at the side of the loom. The knotted bundles of threads to which the stones were



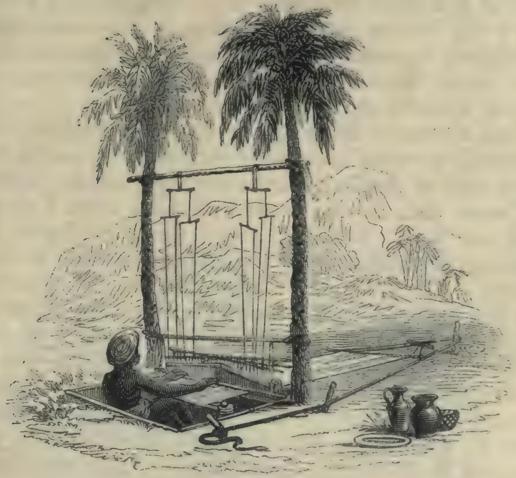
ANCIENT LOOM.

attached, often remained after a web was finished in the form of a fringe. The woof remained upon the spindle, and was either conveyed through the warp without any additional contrivance, as is still the case in Iceland, or it was made to revolve in a shuttle made of boxwood, as in the modern shuttle, the form of which is of great antiquity.

The ancients were well acquainted with various methods of pattern weaving. Striped goods were produced by making the threads of the warp alternately black and white, or of different colours in a certain series, according to the pattern described. The Greeks understood the method of "mounting the loom," as it is now called;—that is, arranging a number of strings so as to separate the warp threads into two or more groups, between which the weft was passed;—the leash (*μίτος*) being one such string, and a woven pattern, being termed *δίμιτος*, *τρίμιτος*, or *πολύμιτος*, according as it contained two, three or

more groups of strings; or, in the language of modern weaving, "leaves of healds" or "heddles." Variegated patterns were also produced by using a warp of one colour only, while the colour of the weft was changed at regular intervals. Checked and striped goods were most probably produced in the first instance by combining the natural varieties of wool, such as white, black, brown, &c. The weft was the medium through which almost every other diversity of appearance and quality was effected. The warp was more twisted, and, consequently, stronger and firmer than the weft. Different kinds of wool were spun for the warp and for the weft. After the piece was woven the fuller drew out its nap by carding. When any kind of cloth was enriched by the admixture of different materials, the richer and more beautiful substance also formed part of the weft. Thus the *vestis subserica* had the weft or tram of silk; in other cases, it was of gold, or of wool dyed with Tyrian purple, or of beaver's wool. Variegated patterns, sprigs, and other ornaments were also woven, and an endless diversity was produced by varying the manner of inserting the materials into the warp.

The loom of the Hindoo weaver at the present day illustrates the most ancient method of weaving among oriental nations. It consists of two bamboo rollers, one for the warp, and another for the woven cloth; and a pair of healds for parting the warp. The shuttle resembles a large netting needle, and is rather longer than the intended breadth of the cloth: it is also used as a lay or batten for driving home the weft. The Hindoo weaver carries this rude apparatus to any tree which may afford shade; here he digs a hole large enough to receive his legs, and the treadles; he then stretches his warp by fastening two bamboo rollers at a proper distance from each other with pins into the turf; the heddles he fastens to some convenient branch of the tree overhead, or to a bamboo rod, as in the accompanying cut; he inserts



HINDU WEAVER.

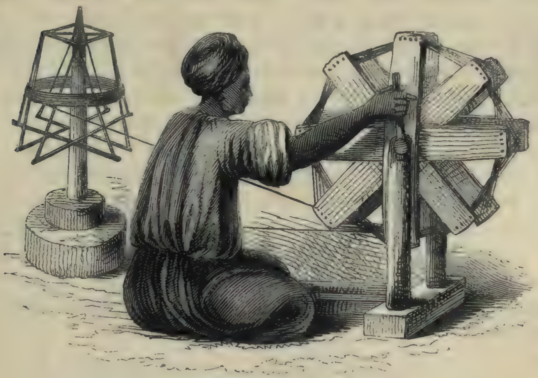
his great toes into two loops, which serve for treadles, and thus raises the alternate threads of the warp, draws the weft, and then strikes it close up to the web with his long shuttle.

Forbes describes the weavers in Guzerat, near Baroche, as fixing their looms at sun-rise under the shade of tamarind and mango trees. In some parts of India, as on the banks of the Ganges, the weavers work under the covers of their sheds, fixing the geer of their looms to a bamboo in the roof. A similar practice is observed in Ceylon, where the weavers commence operations by driving four rude posts into the ground, for the support of the breast-beam, and also for supporting a flat board for raising the web a little behind the healds. The breast-beam has a groove cut into it for the purpose of fixing the end of the web in, but by filling it with water it serves as a level. The mode of levelling the two beams with each other, is by placing a slip of the

rind of a plantain-tree upon them, and, pouring water upon the centre, any inclination is thus easily and accurately ascertained. A hole is dug between the four posts for the feet of the weaver, he himself sitting upon its edge.

The narrative from which these particulars are gathered is thus continued:—"Nothing could be more rude or simple than the different articles used: and some idea may be formed of them when I state, that the loom, including every thing employed in weaving, is purchased for something less than half-a-crown. The warp had been previously put into the heddles and reed. No beam for the warp is used, but the whole reached within a few inches of the ground at once. From the extremity of the web a cord is extended round several stakes driven into the ground, and at last fixed by a sailor's knot to a post close to the weaver, who by slacking off a little as occasion requires, by degrees draws the unwoven part of the web towards himself. Several rods are run through the warp for the purpose of steadying the threads, and preserving the shed or lease, and are drawn out as the web advances. The heddles had only two leaves; instead of treadles two cords descended into the hole with a piece of lead attached to each; and this was taken between the two first toes and so worked. The lay is suspended by two coarse cords. It consists of two pieces of board with a groove in each for the reception of the reed, which is retained by a cord at each end. The shuttle resembles that used in Britain in weaving woollen. At seven o'clock A.M. the loom was tied up, and at nine A.M. he was weaving with great rapidity. The warp was very coarse, but regular, and had been dressed before he came. Rice boiled in water is the substance used for this purpose, and it is applied to the yarn by means of a bit of rag. I detained the operator for several hours in taking sketches, yet he finished his work by two P.M. It might be three

yards long, and the weaving cost nearly sixpence. The weaver seemed to possess a large share of vanity, and was much pleased to show that he could weave with his eyes shut." The weaver was assisted by a pirn-winder, whose implements were also very rude. The weft, which was made up in hanks or skeins, was brought in a leaf, and was wringing wet with paste. "The winder kept five or six pirns only a-head of the



ORIENTAL WINDER.

weaver; but whenever a thread of the web broke, it was his duty to get up and tie it; and, indeed, he had to do every thing out of the reach of the weaver, who could not get out of his hole without unshipping the breast-beam. Thus they went on very sociably together, always working, chewing betel, and conversing. I understand their manner of warping is performed by fixing sticks in the ground at certain distances, and leading the yarn round them which had been put upon the split bamboo, as in filling the pirns, and centre stick held in the hand. The yarn is spun by women with the distaff."

Such appears to have been the manner of weaving among the eastern nations from a very remote period.

From them the knowledge gradually spread to the West, where it has rapidly improved. The period of its introduction into Britain is uncertain. From an obscure passage in Cæsar's Commentaries it is supposed the art was unknown in Britain, when he invaded the island.

A specimen of ancient manufacture is still preserved in the Cathedral of Bayeux. It is a web of linen sixty-seven yards long, and nineteen inches broad, embroidered with a history of the conquest of England by William the Norman, commencing with Harold's embassy, and ending with the battle of Hastings, and Harold's death, in 1066. This specimen of ancient art is supposed to have been executed by Matilda, the wife of the Conqueror; but although it may have been embroidered in England, the cloth on which the figures are wrought was probably the production of some other country.

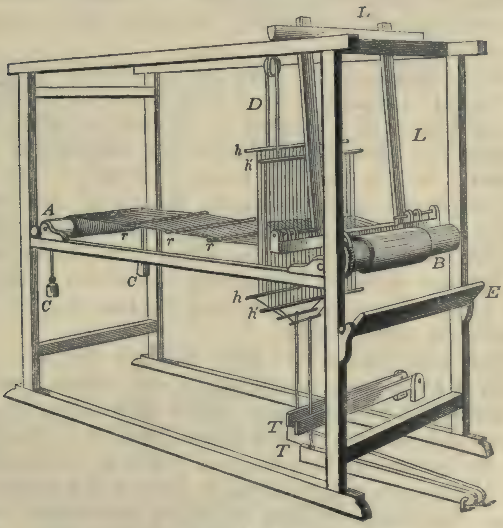
The history of the art of weaving in this country for several centuries after the conquest, is nearly identical with the progress of the woollen manufacture, which has already been noticed.

THE HAND-LOOM.

In former treatises the raw material has been traced through the various processes necessary to convert it into cotton, or linen, or woollen yarn. This yarn is now to be woven into cloth; but, before it is fit for the weaver, it has to undergo several processes, which admit of much better explanation when the action of the common loom is understood.

If we examine a piece of plain cloth, it will be found to consist of two distinct sets of threads, which cross or interlace each other at right angles; the threads which proceed in the direction of the length

form what is called the *warp*,* while the threads which run in the direction of the width of the cloth form the *weft*.† The weft threads pass alternately over and under the warp threads; no one thread, in plain weaving, passing over or under more than one thread at once. This is *plain weaving*, and is performed at the loom, of which the essential parts are:—1. An apparatus for stretching the warp. 2. A contrivance for raising half the strings of the warp, and depressing the other half, so as to open a space for introducing the weft. 3. An instrument for casting the weft between the opened threads of the warp. And 4. A contrivance for striking each weft-thread close up to the one previously thrown.



COMMON LOOM.

* Also called *twist*, *caine*, (from the French, *la chaine*, or the chain,) and *organzine*.

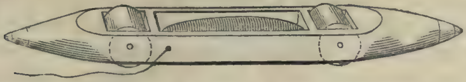
† Also called *woof*, *shoot*, and *tram*.

The frame-work of the loom consists of four upright posts, strengthened by cross beams at the top and bottom, having somewhat the appearance of a four-post bedstead. At one end is the *beam* or *yarn-roll* (A), on which the warp-threads are wound; and at the other end is a similar beam, called the *cloth-beam* (B), on which the woven portion of the work is wound. As the web is wound on the cloth-beam, the unwoven warp is wound off the warp-beam, the whole being kept stretched during the progress of the work by means of iron weights (C), or by a large stone slung over the warp-beam, or by some other mechanical contrivance. The extended threads of the warp are prevented from becoming entangled by means of flat rods (*r*), usually three in number, placed horizontally between the alternate threads of the warp.

The threads of the warp are alternately raised or depressed by what are called the *healds* of the loom (*h*); these consist of a number of twines looped in the middle, through which loops the warp-yarns are drawn. In the simplest form of loom two healds are employed, each alternate thread of the warp being passed through the loops of one heald, while the intermediate threads are passed through the loops of the other heald. The two healds are so united by a rope or pulley (D), that the lowering of one causes the other to rise.

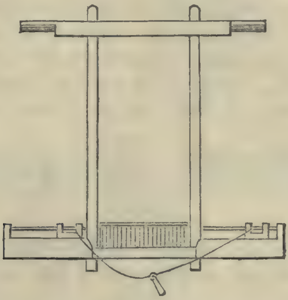
The warp-yarns also pass through the dents or teeth of an instrument called the *reed*, which is set in a moveable swing-frame, called the *lathe*, *lay*, or *batten* (L), because it *beats* home the weft to the web. At the bottom of this frame is a sort of shelf, called the *shuttle race*, along which is thrown the shuttle, a small boat-shaped piece of wood, containing, in a hollow in the middle, the bobbin of yarn which is to form the weft. At the side of the shuttle is a small hole, through which the yarn runs freely as the shuttle moves along. The motion of the shuttle is

sometimes facilitated by the addition of wheels to the under side.



The old method of throwing the shuttle by hand is seldom adopted now, the contrivance of the *fly shuttle*, by John Kay, being used instead. The two ends of the shuttle-race are closed up, so as to form short troughs, in which two moveable pieces of wood, called

pickers or *peckers,* move along wires of the same length as the troughs. To each of these pickers is fastened a string, both strings loosely meeting at a handle, which is held in the right hand of the weaver. When



the shuttle is in one of the troughs, a smart jerk or pull at the picker projects it along the shuttle-race, and another jerk or pull in the contrary direction projects it the other way.

Let us now suppose the weaver to be at his seat (E),

and about to begin work. By pressing upon a treadle (T) with one foot he lowers one of the healds, and consequently all the threads of the warp which pass through its loops will be depressed also; and, at the same time, the other heald, together with its threads, will be raised, thereby leaving a space, called the *shed*,* between the two divisions of threads for the passage of the shuttle.

For every thread of weft thrown across the warp, the weaver has to perform three distinct operations: *first*, he presses down one of the treadles, by means of which every alternate thread of the warp is depressed; *secondly*, into the opening or shed thus formed he throws the shuttle, so as to drive it across the whole web; *thirdly*, with the batten, guided by his left hand, he drives the thread of weft close up to the web. A thread of weft being thus completed, the weaver proceeds in a similar way to form a second thread, but in a reverse order; the warp threads which were before elevated are now depressed, and the shuttle, which was on one side, is now on the other.

The woven cloth, as it is completed, is wound upon the cloth-beam, by turning a handle at the side; the beam being prevented from slipping by a ratchet-wheel. The cloth is kept extended in breadth by two pieces of hard wood, called *temples*, fur-

TEMPLES.

nished with sharp points in their ends, which lay hold of the edge or selvage of the cloth at either side.

It will appear, from the above description, that plain weaving is a very simple operation. It requires, however, some skill and considerable practice to work quickly, and to produce well-woven fabrics.

* See the cut at page 386.

A practical weaver says, that "many tyros in the art so use their feet as to depress the treadles far too suddenly, the bad consequence of which is, that by the sudden relaxation and tension of the threads of the warp, such among them as may at any point be weak, are broken, the tendency to which accident is increased by the greater friction against the dents of the reed. Considerable time is then lost in renewing the broken threads; frequently more than would have sufficed, in the absence of such accidents, for the actual weaving of the goods. The evil is still greater if, through inattention, the shuttle is kept at work after the breaking of one or more warp-threads. Broken threads cannot, of course, retain their relative position with the rest, but cross over, or become interlaced with others, to the manifest injury both of the look and actual quality of the fabric. Frequently, too, these broken threads interfere with the passage of the shuttle, and occasion further mischief by the breaking of other portions of the threads." If the shuttle be thrown too violently it will recoil, and slacken the thread of the weft, and thus injure the appearance of the fabric. "It is also of importance that the batten should be brought forward against the shoot with an equal degree of force at each stroke, otherwise there would be no uniformity in the thickness of the cloth. A knowledge of the degrees of force proper to be applied to fabrics of different natures and degrees of fineness can only be acquired by attention and long practice. An experienced weaver always endeavours so to mount his loom, that the batten shall have such a range or swing as is proportioned to the texture of the goods under preparation. The motion of the batten, as it swings to and fro, is similar to that of a pendulum, tracing the arc of a circle, and the greater or less extent of this arc determines the greater or less degree of force wherewith the shoot is driven home; for which reason it is of importance that the woven cloth should be

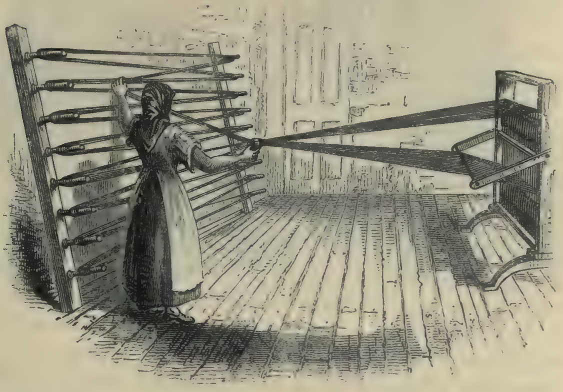
very frequently taken up or wound on the cloth-roll, lest the uniformity of its texture should be interrupted by the diminished range of the batten. In weaving coarse or thick goods, the batten should be hung so as to give it greater play, and consequently more force, than where fine and light fabrics are woven."

The various parts of the loom already enumerated will have to be mentioned again; but it is now time to notice the preparation of the yarn for the weaver.

WARPING.

The yarn, or thread, employed in weaving, is of two kinds, differing from each other in hardness or twist; the hardest or most twisted being used for the warp, and the softer or less twisted for the weft. The yarn or thread is sent from the spinning and doubling mills in hanks, skeins, or cops: the warp threads are wound on bobbins, from which the warps are formed by a process called *warping*, the object of which is to arrange all the warp-threads alongside of each other in one parallel plane. Warping is a delicate and somewhat difficult process to manage. Some idea may be formed of the skill and care required, when it is stated, that a piece of fine silk of not greater width than twenty inches, may have the breadth of its warp made up of more than eight thousand threads, each one of which must be so accurately disposed in its proper station as to avoid entanglement or confusion throughout its whole extent. The ancient method was to draw out the warp at full length in an open field, a practice still observed in India and China; but in a land of mechanical invention, and in an uncertain climate, this primitive method would soon be abandoned. One of the oldest contrivances in the factory is the

warping-frame, consisting of two upright sides, containing a number of wooden or iron pins, for receiving



WARPING-FRAME.—(*Woollen-yarn.*)

the yarns. The bobbins being contained in a frame, the warper ties all the ends of the threads together, and attaches them to one of the pins; then gathering all the threads in his hand into one clue, and permitting them to slip through the fingers, he walks to the other end of the frame, where he passes the yarns over the fixed pin; and thus walks backwards and forwards until he has collected enough yarn to form the warp. This work is sometimes performed by females, as shown in the cut.

The most usual method of warping is by the *warping-mill,* which consists of a large reel or frame-work of wood, with twelve, eighteen, or more sides, so as to serve for measuring exactly upon it the total length of the warp. This frame-work is mounted upon a vertical axis, to which motion is given by means of an endless band, connecting the bottom of the axis with a wheel turned by the warper.

A sufficient number of bobbins filled with yarn

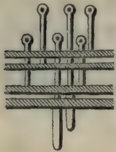
WARPING-MILL.—(*Worsted-yarn.*)

must be taken to form the length of the intended piece of cloth. One-sixth of the number of bobbins required is usually mounted at once in a frame called a *travers*. The bobbins are set loosely upon wire skewers or spindles, so as to revolve and give off the yarn freely.

The threads pass from the bobbins to the frame through an instrument called a *jack* or *heck-box*, or simply a *heck*. This is made to slide up and down one of the upright posts of the frame, or between two uprights at the side of the frame, by being suspended by a cord, which, passing over a pulley at the top of the post is carried and made fast to the axle; so that as the reel revolves, the heck is gradually raised, from the bottom to the top, and when the mill is turned the other way it descends by its own weight, and thus the band of warp-yarns is wound spirally and smoothly from the top to the bottom of the reel.

The use of the heck is to divide the warp-threads into what is called the *lease*, that is, into two alternate sets, one set for each heald. For this purpose the heck-block contains 120 or more steel pins, with a

round hole or eye in the upper end of each, through which a thread passes in the process of warping. The pins are placed alternately in two frames, so arranged that either may be raised at pleasure. A front elevation of a part of the heck is given in the figure, for



the purpose of showing more distinctly the method of lifting the alternate threads when required, so as to form the lease. It is of the utmost importance to preserve the lease in every stage of the operation of weaving, as the regularity of the warp-yarn in the loom depends upon it. The steel pins must be finely polished and hard tempered for the sake of smoothness, and to prevent the eyes from being worn by the friction of the threads passing through them.

The proper number of bobbins being mounted in the frame, the threads are then passed through the eyes of the heck, and the whole being knotted together, are fixed to the pin upon the mill. The mill is then turned slowly until the top lease pins come nearly opposite the heck. The warper then, lifting half of the heck-frame or thread-guide, passes the fore-finger of his left hand through the space formed between the threads which are raised and those that remain stationary. Into this space he inserts his thumb, and carefully places the yarn upon two pins of the mill, the first pin passing through the interval kept by his fingers, and the second through that kept by his thumb. Every alternate thread is thus crossed, and the lease is formed. When the warp has formed a spiral line round the frame from the top to the bottom, the threads are again passed over pins; the motion of the frame is then reversed, and the warp forms another spiral line in a contrary direction; the operation being thus repeated until the proper number of threads are collected to form the length of the cloth. The lease, or crossing of the threads, is now preserved by a band tied through them at the top, and

by another band at the bottom, and the warp is then removed by the warper, who generally takes it off from the lower pins, and winds it upon a stick or round his left hand in the form of a gigantic ball of string. A peculiar twist of the hand is required in making this ball, and it is not unusual with beginners to bind up their hand, so that it cannot be extricated without undoing all their work. When the ball is properly made it admits of being unwound from the centre like a ball of string. The length of a cotton-warp varies from four to six hundred yards.

Warping is light delicate work, requiring a quick eye and a gentle hand. It is usually performed by young women. The principal care required is to watch for broken threads, which must be immediately tied, for if this were neglected, a deficiency would be occasioned in the warp, injurious to the appearance of the web, or productive of much annoyance to the weaver.

The appearance of the warping-room is very pleasing, especially where the warps consist of various colours, as was the case when the writer visited Messrs. Ackroyd's worsted-mill at Halifax. From twelve to twenty large frames were whirling round in different parts of a large room. At Mr. Houldsworth's cotton-mill at Manchester, where very fine yarns were being warped, the bobbin-frames were circular, or rather segments of cylinders; and as the white, delicate threads proceeded from them, they had very much the appearance of the rays of light, in what is called in optics a caustic curve.

BEAMING.

When the weaver has received the warp of yarn from the warper, he proceeds to spread it out in regular order upon the yarn-beam of his loom, so as

BEAMING.—(*Cotton Yarn.*)

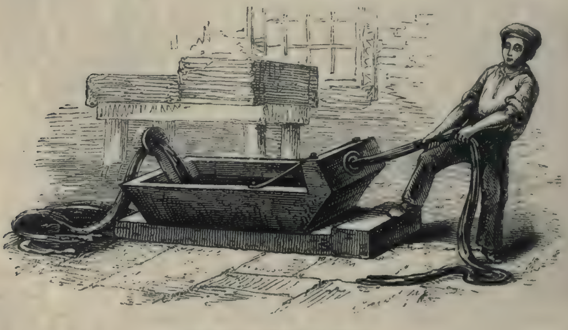
to form the breadth of the intended cloth. This beam turns upon iron pivots, and motion is given to it by putting it in gear with a revolving shaft. For the purpose of spreading the warp-threads uniformly over the beam in the order in which they were laid by the warper, the weaver holds in his hand a rude sort of instrument called a *separater* or *ravel,* which consists of a number of shreds of cane fastened together, and fixed to a rail of wood like the teeth of a large comb. By passing through these teeth, the warp is spread out on the beam to the intended width.

The above cut is from a sketch made at Messrs. Crewdson and Co.'s cotton-mill at Manchester. The weaver unrols the bundle of warp-yarn upon the floor; passes it over two slings in the roof, then through a funnel mouth round a series of pegs, and so backwards and forwards over rollers, during which it is gradually spread open until it arrives near the yarn-beam, where the weaver stands with his ravel.

DRESSING AND SIZING.

In the process of weaving, the warp-threads are subject to very considerable tension and friction, so that if they were stretched in the loom in the same state in which they are spun they would be constantly breaking; and in the case of the finer yarns it would be quite impossible to weave. A dressing of glue, size, or paste is, therefore, given to the yarns, which improves their strength and tenacity, and causes the minute fibres which, as it were, feather the yarn, to adhere closely to it, so that the warp becomes smooth like catgut.

In the sizing of woollen warps, glue is most commonly used. At Mr. Brooke's factory, near Huddersfield, the arrangement shown in the cut was adopted. The warp being coiled on the floor, one



SIZING.—(*Woollen Yarn.*)

end is taken up and passed through a hole in the side of a trough containing a solution of glue, then under two rollers at the bottom of the trough, and, lastly, it is pulled out at another hole on the opposite side. This is repeated several times, because it is well known that yarns and stuffs are not well penetrated

by a fluid if they are not alternately immersed in the fluid, and then squeezed out again for the purpose of expelling the air contained in the fibrous matter. When the woollen yarn is sufficiently dry a very small quantity of tallow is rubbed over it.

In the worsted manufacture it is necessary, before the process of weaving is begun, to get rid of the oil so plentifully used on the long wool in the process of combing. For this purpose the warps are scoured in a large tub of soap-suds, as shown in the annexed cut.

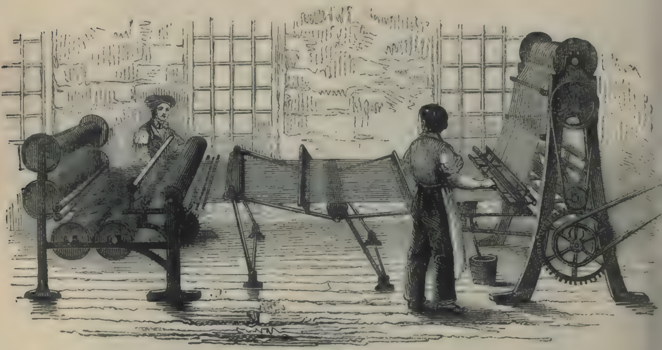
SCOURING WORSTED-YARNS.

The yarns are then passed over a guide-roller between three pair of pressing-rollers, by which means the moisture is got rid of; they are then *linked*, that is, platted in a peculiar manner, to prevent the warp threads from getting entangled with each other, and also to occupy a small space: and each bundle can be readily undone by pulling out one end.

In dressing cotton and linen yarns, a paste of fine flour is used; but as this dries soon and makes the yarn brittle, brine is sometimes added to attract moisture. Hand-loom weavers are accustomed to

work in damp sheds to prevent the size of the warp from drying and hardening.

The dressing and sizing of cotton-yarn is commonly performed at a machine consisting of frames for carrying rollers which have been filled with warp-yarn. The threads pass through a kind of reed to keep them distinct, and then between two rollers covered with felt, one of which dips into a trough containing paste. The lower roller gives size to the yarn, while the upper one squeezes out the superfluous quantity. The paste is rubbed into the fibres of the yarn, and smoothed over by means of brushes

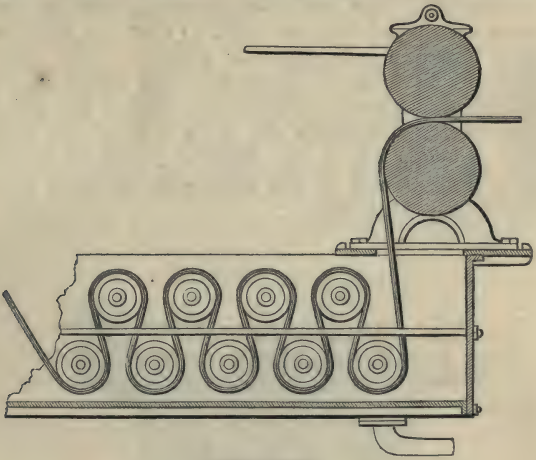


DRESSING AND SIZING.—(*Cotton Yarn.*)

arranged in a cylindrical form, one over and one under the warp, moving in a direction contrary to that of the yarns. Flat brushes are also sometimes used, as was the case at Messrs. Crewdson and Co.'s cotton-mill, from which the above cut is taken.

The warp is dried by passing it over a box or chest filled with steam, a current of air being promoted by means of a revolving fan. After this it is wound upon the main yarn-beam, which is to be put into the loom; the regular winding of the warp being promoted by passing it through a reed in its passage to the beam.

There is also another method of dressing yarns by means of the sizing machine. This consists of an iron trough furnished with a steam jacket, and nearly filled with fluid paste. Within the trough a series of copper rollers are arranged in two rows, as in the figure, over which the warp travels up and down.



SIZING-TROUGH.

These rollers turn by the friction of the travelling warp, by which motion the warp is pressed tight upon the rollers, and left loose in the space between every two of them; by this means a complete impregnation of the fibres of the yarn takes place. Two rods extend the length of the trough on either side of the warp to keep it in the centre of the rollers. The warp having passed all the rollers is squeezed between two large wooden rollers, which expels all superfluous moisture: the warp is then led over the cylinders of a drying machine, or wound up in a bundle, and conveyed to a hot room to be dried.

DRAWING IN.

THE warp being regularly wound on the warp-beam, the weaver must pass every yarn through its proper eye or loop in the healds. This is called *drawing in.* The healds are hung up, and the yarn-beam is suspended by its ends, so that the warp may hang down in perpendicular threads. The weaver then sits in front of the healds, and another person behind picks up every thread in its order, and delivers it to be drawn through the open eyes of the healds. The order in which the threads are to be taken is easily ascertained by the lease-rods, as every thread crosses that next to it.

DRAWING IN.—(*Woollen Yarn.*)

After the warp has been passed through the loops of the healds, it is drawn through the reed by a hook, two threads being passed through each split in the reed.

The lease-rods being inserted in their proper places, the first thread will be found to pass over the first rod and under the second; the next thread passes under the first and over the second, and so on alternately. By this contrivance every thread is kept distinct, and if broken, its place can be easily found. The third rod divides the warp into *splitfuls*, two threads passing alternately over and under it.

As these operations proceed, the warp is knotted together in small portions, and when complete they are tied to a shaft and connected by cords to the cloth-beam; the yarns are then stretched in the loom, ready to begin the weaving.

The regularity of cloth depends greatly upon the evenness of the dents of the reed, and if this is neglected, the warp will be liable to break, and the texture of the cloth be injured.

The fineness of the cloth, or, as the weavers term it, the *number* or *set of the reed*, depends upon the number of dents of the reed in a given length, two threads passing through each dent. Various methods are in use for computing this in different places. Thus a "sixty reed" cloth at Blackburn and at Stockport, does not indicate the same degree of fineness. But the method in use at Stockport is the most simple, and consequently the most useful. The fineness is estimated according to the number of threads of the warp in an inch; thus, a Stockport sixty reed cloth contains sixty warp threads in an inch. A Blackburn, a Bolton, and a Scotch "forty reed," would all vary in fineness. A uniform system is much wanted, and that of Stockport seems to be the best.

PATTERN WEAVING.

In plain weaving, the warp and the weft are of the same colour, and usually of the same degrees of fineness. The thickness or texture of plain goods depends upon the proportion which the fineness of the yarn bears to the measure or *set* of the reed. If yarns of different degrees of fineness are introduced into the same web, at regular intervals, two distinct textures or qualities of cloth will be produced, and the appearance of these will be different when the web is finished. This will produce a sort of striped pattern, which may be varied in many ways, as will be noticed presently. The greatest variety, however, is produced by the introduction of colour, of which the simplest case is that in which all the warp threads are of one colour, and the weft of another colour. This produces what are called *shot* patterns, but the arrangement of the looms is the same as in plain weaving. In the production of *stripes* a new arrangement of the threads either of the warp or of the weft is required. If the stripes run in the direction of the length of the cloth, the variation is chiefly the business of the warper, who arranges the warp in such a manner that the two colours shall succeed each other at regular intervals. The effect may also be produced by yarns of the same colour, but of different degrees of fineness, as noticed above, or by drawing a greater quantity of warp through a given number of healds, or intervals of the reed, where the stripes are to be formed. For example, two or more threads may be drawn through the same heald eye, or three or more healdfuls may pass through the same interval of the reed; or lastly, if the stripe is to be very thick, both these methods may be adopted. Where

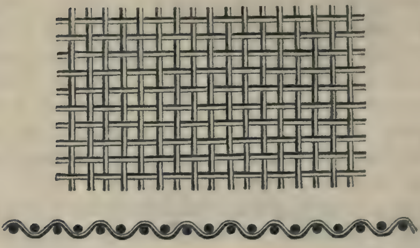
large quantities of striped goods of the same description are to be made, the stripes are commonly formed in the warping, because they can be made much more uniform in the warp than in the weft. When the stripes extend across the cloth, the warp is arranged as in plain weaving, but the weaver uses two or more shuttles containing coloured threads, which are thrown at regular intervals.

Checks are merely a combination of the two methods of striping. The warper first produces an alternation of colours in the warp; and the weaver produces a further mixture of colours by throwing in wefts of different colours, from two or more shuttles, at certain intervals, according to the pattern, which depends upon the comparative width of the stripes. Stripes and checks are manufactured in great quantities from all the different materials, especially from worsted, silk, and cotton. When the pattern of checks is different at the borders from that of the middle or *bosom* of the web, they are called *shawls*, or *handkerchiefs*.

TWILLED CLOTH.

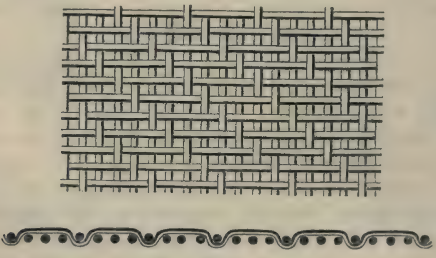
Twill, or *tweel*, (said to be derived from the French, *touaille*,) comprises an extensive variety of woven fabrics, such as satin, bombazeen, kerseymere, &c.

In plain weaving every thread of the warp and weft cross alternately at right angles, as in the following figure, which represents the appearance of a piece of plain cloth, when viewed through the microscope; the intersections of the threads are evidently alternate, as seen in the vertical section.



PLAIN WEAVING.

This, however, is not the case with twilling, for in this variety of weaving only the third, fourth, fifth, or sixth, &c. threads cross each other. The accompanying figure is a magnified representation of a piece of tweeled cloth. The same thread of weft remains *flushed*,* or disengaged from the warp, while passing *over* three threads, and is held down by passing *under* the fourth. If this cloth were turned upside down, the same appearance would take place in the warp, every fourth thread would appear interwoven with the weft, and the remaining three threads would be flushed. The following plan and vertical section will show this arrangement more clearly.



TWILLED WEAVING.

* When any thread or portion, whether of warp or weft, is not regularly interwoven in the cloth, as in plain weaving, that thread, or portion of thread, is said to be *flushed*.

In twilled cloth the points where the threads of the warp and weft cross or interweave are more marked to the eye, because both threads are there seen together. These points take the form of diagonal lines, extending parallel to each other across the face of the cloth, and the degree of obliquity will vary according to the number of warp threads passed over without interlacing with the weft. In the coarsest, or *blanket twill*, every third thread is crossed. In finer fabrics the threads intersect each other at intervals of four, five, six, seven, or eight threads; and in some silk stuffs, the crossing does not take place until the sixteenth interval: this is called the *full satin twill*.

It is obvious that these effects cannot be produced at the loom as mounted for plain weaving, where two healds receive the warp threads alternately. In twilled cloth, a number of healds is required equal to the number of threads contained in the interval between each intersection inclusive. Thus, when every third thread is to be interwoven, three leaves are required, if every sixth thread, six leaves, and so of all the others. Thus the different species of twills are distinguished by the number of leaves required in weaving them, as a *four-leaf twill*, a *five-leaf twill*, and so on. The figure given above is a four-leaf twill.

This variety of weaving is adopted for fabrics in which great strength, thickness, and durability are required. It is very common in the silk manufacture, where it is frequently used for the display of colour.

It does not appear, at first view, why twilled cloth is stronger than plain; on the contrary, one would rather suppose the larger the number of intersections of the warp and the weft, the stronger and more durable would be the cloth. Such, however, is not the case. The durability of a woven fabric depends partly on its strength and partly on its flexibility. The larger the quantity of materials collected within

a given space, the greater will be the durability of the cloth. Twilling enables the weaver to combine a greater quantity of materials within a given space than plain weaving. There is also another reason why twilled cloth is superior to plain. In plain cloth, closely woven, the threads deviate very considerably from a straight line; they follow a serpentine course, throughout the length and breadth of the cloth: this renders it liable to be easily cut or chafed, especially when composed of hard and comparatively inflexible materials, such as flax: hence this defect is mostly observable in stout linens. In twilled cloth, on the contrary, as the threads only cross at intervals, the deviation from the straight line is much less, and the flexibility of the cloth, of course, much greater.

FIGURE WEAVING.

As almost every variety of fancy weaving is produced by the order and succession in which the weft is interwoven with the warp, the principal difference in mounting the looms is in the number and arrangement of the healds, and the apparatus for moving them.

Figures, flowers, or patterns of any other kind, are produced by dividing the warp between a number of healds, which can be lowered at pleasure by separate treadles, while threads of different colours may be either concealed or brought forward upon the face of the fabric, or be made to change places according to the pattern.

Where the weft threads vary either in colour or substance, various shuttles are provided, each containing its own peculiar thread; and to enable the weaver to substitute one shuttle for another without much trouble or loss of time, one or both of the troughs connected with the shuttle race, is divided into various compartments, each containing a shuttle. By a simple contrivance, this trough is made to swing

round, or backwards and forwards, so as to bring one of its divisions, containing the shuttle required, opposite to the shuttle race.

In weaving complicated patterns, the number of healds would be so great, that one man could not possibly manage them with his feet; and if he were to attempt to do so, he would be constantly liable to depress the wrong treadle, and consequently, to injure his work by spoiling the pattern. To meet this difficulty, an apparatus called the *draw loom* was invented, by means of which the most elaborate patterns could be produced, requiring, on the part of the weaver, no greater attention than is bestowed in plain weaving.

The draw loom is, in appearance, a complex piece of machinery, although in principle it is very simple, being nothing more than a contrivance for raising particular warp threads in the order required by the pattern. For this purpose the warp threads pass through loops made in vertical strings, each thread having one string. These strings are so arranged in separate groups, that an attendant boy, called the *draw boy*, by pulling the handle which unites one group, draws up all those warp threads which require to be elevated for one particular passage of the shuttle. The order in which the threads are grouped is previously arranged on a pattern paper, or *design*, as it is called. This paper is divided by lines into small squares, representing a woven fabric, and upon it the pattern is drawn and coloured. It then serves as a guide in arranging and grouping the various threads of the draw loom, or *building the monture*, as it is called. The order of succession in which the handles are to be pulled, or drawn, is also arranged, so that the weaver and his draw-boy have only a simple task to perform.

But simple as may appear the task of pulling a number of handles in a certain order of succession, it is liable to one of the numerous errors pertaining

to every work performed by human hands. The pattern would be thrown out and injured if the boy were to pull the wrong handle, an accident most likely to occur in the course of a long day's work. This objection was remedied by the invention of a most ingenious piece of mechanism, which retained the name of the *draw-boy*, because it performed his work. It consisted of a half wheel, the rim or periphery of which was grooved, so as to catch into the various strings required to be pulled down. This half-wheel travelled along a rack, or toothed bar, oscillating, at the same time, from right to left, and drawing down particular cords as required to form the pattern, thus removing all possible chance of mistake by depressing the wrong handle.

Another objection to the draw loom, which belonged to the nature of the apparatus, was the length of time required for building the monture and cording the loom, one man being occupied three or four months in these necessary preliminaries, and then the loom would only serve for one particular pattern. The introduction of a more effective, and less complicated system has therefore superseded the draw loom.

THE JACQUARD LOOM.

The inventor of this beautiful apparatus was originally a straw hat manufacturer at Lyons, and his attention was first attracted to the subject of mechanism by accidentally seeing an announcement in an English newspaper, that a premium would be awarded by a society in this country to any person who should weave a net by machinery. This seems to have roused his mechanical powers, and he accordingly set to work to produce the required contrivance. In this he was successful; but it appears that the pleasure of success was the only reward which he coveted, for he threw aside the machine as soon as

it was completed, and afterwards gave it to a friend as a trifle in which he no longer took any interest. The net woven by this machine came, by some means, to the knowledge of some persons in authority, and was by them sent to Paris. M. Jacquard had entirely forgotten his production when he was sent for by the prefect of Lyons, who asked him if he had not directed his attention to the making of nets by machinery. He did not immediately recollect the circumstance to which the prefect alluded, but when the net was produced he remembered it. The prefect then ordered him to produce his net-weaving machine. Jacquard asked three weeks for its completion, at the end of which time he carried his invention to the prefect, and directing him to strike some part of the machine with his foot, a knot was added to the net. The ingenious contrivance was sent to Paris; and it is singularly illustrative of Napoleon's arbitrary government, that the inventor, instead of being invited, or even requested, to visit Paris, was immediately placed under arrest, and conveyed to that city in the custody of a gens-d'arme, a step that was taken so suddenly that he was not permitted even to go home to provide himself with the requisites for his journey. When arrived in Paris, he was required to produce his machine at the Conservatory of Arts, and submit it to the examination of inspectors. This proving satisfactory, he was introduced to Napoleon, and to Carnot, the latter of whom said to him with a look of incredulity, "Are you the man who pretends to this impossibility—who professes to tie a knot in a stretched string?" In answer to this inquiry the machine was produced, and its operation exhibited and explained. In this strange way was Jacquard's first mechanical experiment brought into notice and patronized. He was afterwards required to examine a loom on which between twenty and thirty thousand francs had been expended, and which was employed in the production

of articles for the use of Buonaparte. Jacquard offered to effect the same object by a simple machine, instead of the complicated one by which the work was sought to be produced,—and improving on a model of Vaucanson, produced the mechanism which bears his name. A pension of a thousand crowns was granted to him by the government, as a reward for his discoveries, and he returned to Lyons. So violent, however, was the opposition made to the introduction of his loom, and so great was the enmity he excited in consequence of his invention, that on three occasions he had the greatest difficulty in escaping with his life. The *Conseil des Prud'hommes*, who are appointed to watch over the interests of the Lyonese trade, broke up his machine in the public *Place*; "the iron (to use his own expression) was sold for iron—the wood for wood, and he, its inventor, was delivered over to universal ignominy." *

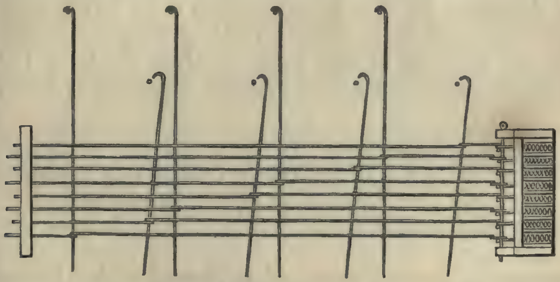
The invention was too valuable not to have found its way into other countries, which, by its means, were enabled to rival, and even surpass the products of the French loom. Then it was that the Lyonese weavers saw the folly of their opposition, and condescended to adopt the invention of the man they had so cruelly persecuted. The Jacquard apparatus is now extensively employed through the whole of the silk, worsted, and muslin manufacturing districts of France and England. A short time ago the French house of Didier, Petit & Co. produced one of the most extraordinary specimens of silk weaving that has probably ever been executed. It is a portrait of Jacquard, representing that extraordinary man in his workshop surrounded by his implements, and "planning the construction of that beautiful machinery, which now, in its increased perfection, returns

* These particulars were related by M. Jacquard himself to Dr. Bowring, who stated them in his evidence before the Committee of the House of Commons appointed to inquire into the state of the silk trade.

this testimony to the genius of its inventor." This work, worthily entitled *Hommage à J. M. Jacquard,* was woven with such truth and delicacy as to resemble a fine line engraving. There were a thousand threads in each square inch French, in both the warp and the weft.

The Jacquard apparatus is not a loom, but an appendage fixed on the top of the loom, in a perpendicular line with its healds, and is intended to elevate the warp threads for the passage of the shuttle. It will be understood from previous details, that in figure weaving, in addition to the ordinary play of the warp threads for the formation of the ground of the web, all those threads which should rise simultaneously to produce the figure have their appropriate healds. In the draw loom these were raised by means of cords, which grouped them together into a system in the order and at the time required by the pattern. In the Jacquard apparatus, the object is attained in the ingenious manner now about to be explained.

The warp-threads are raised by a number of wires arranged in rows, and each wire is bent at the upper part into the form of a hook. These hooks are supported by bars, the ends of which are seen in the

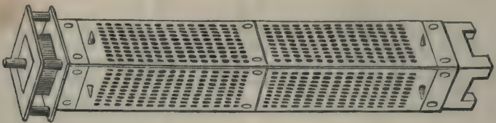


figure, their number being about equal to the rows of lifting hooks. The bars are supported by a frame,

which is alternately raised or lowered by a lever attached to, and acting with, the treadle. If all these bars are raised at the same time, all the warp-threads will, of course, be elevated; but if by any means some of the hooks are pushed off the bars, while others are allowed to remain on, it is clear that the warp-threads in connexion with the latter only will be raised. The hooks are disengaged from the bars by horizontal wires or needles, furnished with

loops or eyes in the centre, through which the lifting-wires are made to pass. The horizontal needles are kept in their place by a number of spiral springs contained in a frame, the points of the needles protruding on the opposite side. Now, if a slight degree of pressure be applied to any of the points, the needles will be driven into the frame, the hooked wires which pass through them will be disengaged from the bars, and the warp-threads in connexion therewith will not be raised. On the removal of this pressure, the elasticity of the springs will again drive the needles forward, and again place the hooks upon the bars.

The next feature to be considered in this apparatus is the means for causing the needles to be driven back at the proper time, so as to raise or depress the different portions of the warp in order to form the pattern. This is managed by a revolving bar of wood,



containing four or more sides, pierced with a multitude of holes, answering in number and position to the points of the needles. One of the sides of this

bar is brought up against the points of the needles at each depression of the treadle.

It is obvious that if this bar were opposed to the points of the needles, the points would enter the holes and no effect be produced; but if some of the holes were stopped, while others remain open, some of the needles would be driven back, while others remain undisturbed, and the warp-threads in connexion with the latter only would be raised. This is accordingly done. Some of the holes in each face of the revolving bar are stopped, or covered by a card, which contains holes of the same size as the bar, but fewer in number; so that when the points of the needles meet with an unperforated part of the card, they are driven back, but when the points enter the holes of the card, the needles remain unmoved: in this way the intended pattern is made out, the revolving bar presenting a new card to the points of the needles at every quarter revolution, supposing the bar to be four sided.

As the holes in the cards are so arranged as to raise in succession those healds which will make out the intended pattern, it is necessary to have as many cards as there are threads of weft to complete the pattern. Where the pattern is large, or variegated, the number of cards is very considerable. In weaving the portrait of Jacquard, noticed at page 42, as many as 24,000 cards were required, each card being large enough to receive 1,050 holes. All the cards are fastened together by threads, so as to form a kind of endless chain, one complete revolution of which makes out the pattern, and by continually working this, the pattern may be repeated many times in one warp.

The preparation of these card-slips for the composition of the different patterns is a distinct business from that of the weaver. The pattern is first drawn upon squared paper, upon an enlarged scale, as already noticed at page 39, and then repeated in a frame containing a number of vertical threads, answering to

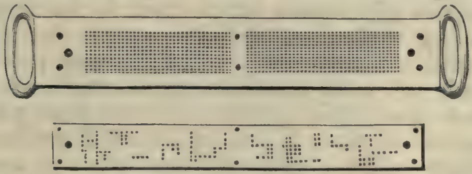
the warp of the goods; the workman then, with a very long needle, takes up such threads as are intersected by the pattern, inserting a cross thread under them, and carrying it over all the remaining threads in the same line, repeating this process until he has inserted such a number of weft threads as will make out the pattern. This being done, the threads thus interlaced are attached to a card-punching machine. This is similar in principle to the Jacquard apparatus; being provided with lifting cords, and wires, and needles, all connected as already described, so that by pulling the lifting-cords the needles will be protruded. In front of these needles, and answering to the revolving bar, is a thick perforated iron or steel plate, each of the perforations of which contains a moveable steel punch, or cutter, of a cylindrical form, so that the protrusion of any of the needles will drive forward their corresponding punches, and deposit them in another similarly perforated iron plate, placed against the face of the one just noticed.

JACQUARD CARD-MAKING MACHINE.

This being understood, it is necessary to notice the arrangement for protruding the steel punches.

One end of each warp-thread is connected in succession with the individual lifting-cords of the machine; each thread of the weft is then taken by the two ends and drawn upwards, by which means all the warp-threads passed under by this weft-thread will be raised, and can be collected together in the hand; by pulling them, the particular lifting-cords to which they are attached will protrude the needles, and these in their turn will drive out the cylindrical cutters from the perforations in the fixed plate, into the corresponding cavities of the moveable plate.

The plate being thus furnished with its cutting punches, a blank card-slip is placed upon it, and both are removed to a press, where the punches are driven through the card-slip. The process is then repeated for the other cards required to make up the pattern; the various cards are numbered and attached together in their proper order. The following figure



PERFORATED PLATE AND CARD.

represents the moveable plate with the perforated card. The larger black spots in the plate are guide holes, corresponding to those in the cards, which are used for tying the various cards together.

The set of cards required to form a particular pattern, when not in use, is made up into a bundle and carefully preserved, with a numbered label and a portion of the fabric attached to it, so that the manufacturer may know at a glance what set of cards to employ for any particular pattern.

When the Jacquard apparatus was first introduced, the cards were formed into an endless chain above the loom, requiring of course, in elaborate patterns,

a great height, so that it was not uncommon for the weaver to cut away the ceiling of his room to make way for the chain of cards. This inconvenience has been remedied by arranging the chain of cards in several folds, supporting them partially upon a curved board. The general arrangement will be seen in the frontispiece, which shows a portion of the interior of Messrs. Ackroyd's loom-shed at Halifax. This contains about eight hundred power-looms, a large proportion of which are mounted with the Jacquard apparatus.

Our brief notice of this ingenious contrivance cannot be better concluded than in the words of Mr. Porter: — "The Jacquard loom has entirely taken the place of every other method of figured silk weaving, and has been, in no small degree, instrumental in bringing that curious and beautiful art to its present state of advancement. The elaborate specimens of brocade which used to be brought forward as evidence of skilfulness on the part of the Spitalfields weavers of former days, were produced by only the most skilful among the craft, who bestowed upon their performances the most painful amount of labour. The most beautiful products of the loom in the present day are, however, accomplished by men possessing only the ordinary rate of skill, while the labour attendant upon the actual weaving is but little more than that demanded for making the plainest goods."

OTHER METHODS OF WEAVING.

Several varieties of the loom remain to be noticed, some of which will find a place in the treatises on the manufacture of carpets and of hosiery and bobbin net. An ingenious *barrel* or *cylinder* loom has lately been introduced into the carpet manu-

facture. The pattern intended to be produced is arranged in relief upon the surface of a barrel or cylinder, precisely in the same way as tunes are disposed on the barrel of the common organ, or on that of a musical box, by inserting wire staples or wooden pins. The barrel being placed upon the top of the loom, these staples act upon suitable mechanism, which raises the warp threads in the order required for working out the pattern.

MECHANICAL OR POWER WEAVING.

In the preceding details, the weaver has been supposed to work the loom in the manner described, by alternately depressing the treadles, throwing the shuttle between the alternate threads from one hand to the other, and driving home the weft by the batten. It was for many years a splendid mechanical problem, how to perform these delicate and somewhat complex operations entirely by machinery. Towards the end of the seventeenth century, the drawing and description of a loom for mechanical weaving was presented to the Royal Society of London by its inventor, M. de Gennes. It is described as "A new engine to make linen cloth, without the aid of an artificer;" and its various advantages are thus stated: —"1. That one mill alone will set ten or twelve of these looms at work. 2. The cloth may be made of what breadth you please, or, at least, much broader than any which has been hitherto made. 3. There will be fewer knots in the cloth, since the threads will not break so fast as in other looms, because the shuttle that breaks the greater part can never touch them; in short, the work will be carried on quicker and at less expense, since, instead of several workmen which are required in making up of very large cloths, one boy will serve to tie the threads of several looms as fast as they break, and to order the quills in

the shuttle." All these advantages apply equally well to the modern power-looms; but it does not appear that M. de Gennes' machine succeeded any more than many other similar contrivances, which were introduced at various times during the eighteenth century, until the attention of mechanists was fairly drawn to the subject by the invention of Dr. Cartwright, the origin of which has been stated in his own words. He says:—"Happening to be at Matlock, in the summer of 1784, I fell in company with some gentlemen of Manchester, when the conversation turned on Arkwright's spinning machinery. One of the company observed that, as soon as Arkwright's patent expired, so many mills would be erected and so much cotton spun, that hands never could be found to weave it. To this observation I replied, that Arkwright must then set his wits to work to invent a weaving-mill. This brought on a conversation on the subject, in which the Manchester gentlemen unanimously agreed that the thing was impracticable; and in defence of their opinion they adduced arguments which I certainly was incompetent to answer, or even comprehend, being totally ignorant of the subject, having never, at that time, seen a person weave. I controverted, however, the impracticability of the thing by remarking, that there had lately been exhibited in London an automaton figure, which played at chess. 'Now you will not assert, gentlemen,' said I, 'that it is more difficult to construct a machine that shall weave, than one which shall make all the variety of moves which are required in that complicated game.'*

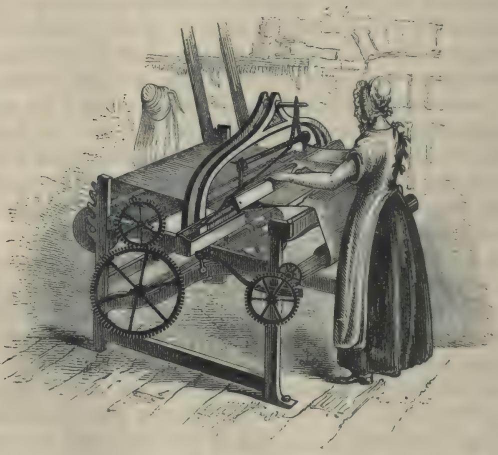
"Some little time afterwards, a particular circum-

* At the time when this observation was made, it was generally believed that Kempelen's chess automaton actually played by machinery; but it has since been discovered that the chief merit of the machinery was in concealing the living player, shut up within it, while apparently every part of the chest containing it was exposed to public view before the game was commenced.

stance recalling this conversation to my mind, it struck me that, as in plain weaving, according to the conception I then had of the business, there could be only three movements which were to follow each other in succession, there would be little difficulty in producing and repeating them. Full of these ideas, I immediately employed a carpenter and a smith to carry them into effect. As soon as the machine was finished, I got a weaver to put in the warp, which was of such materials as sail-cloth is usually made of: to my great delight a piece of cloth, such as it was, was the produce. As I had never before turned my thoughts to anything mechanical, either in theory or practice, nor had even seen a loom at work, or knew anything of its construction, you will readily suppose that my first loom must have been a most rude piece of machinery. The warp was placed perpendicularly; the reed fell with a force of at least half a hundred weight; and the springs which threw the shuttle were strong enough to have thrown a Congreve rocket; in short, it required the strength of two powerful men to work the machine at a slow rate, and only for a short time. Conceiving, in my great simplicity, that I had accomplished all that was required, I then secured what I thought a most valuable property by a patent, 4th of April, 1785. This being done, I then condescended to see how other people wove; and you will guess my astonishment when I compared their easy modes of operation with mine. Availing myself, however, of what I then saw, I made a loom, in its general principles nearly as they are now made: but it was not till the year 1787 that I completed my invention, when I took out my last weaving patent, August 1, of that year."

Dr. Cartwright endeavoured to turn his invention to profitable account, by establishing a power-weaving mill at Doncaster; but his loom required so much modification and improvement before it could be got

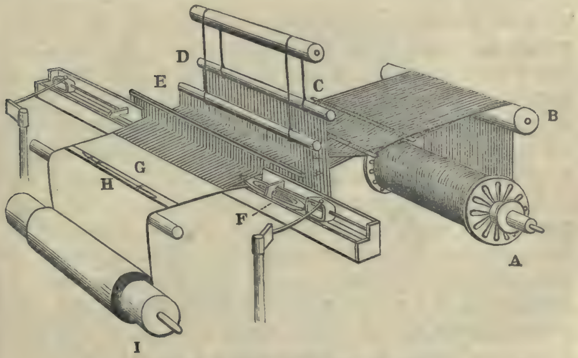
to work satisfactorily, that he expended a sum of money equal to between 30,000*l.* and 40,000*l.* in effecting and patenting his various improvements; and, after all, was compelled to abandon his manufactory. He was denied all profitable use of his patents, by one of those untoward circumstances which have so often obstructed the progress of invention. In 1791, a factory was erected at Manchester, calculated to contain four hundred power-looms, and an agreement was made with Dr. Cartwright for a licence to use his patent. But the operative weavers, fearing lest the employment of power-looms should deprive them of work, regarded this establishment with extreme dislike. No sooner was it erected, and a few looms at work, than the building and machinery were wilfully destroyed by fire. The weavers also determined to oppose the erection of any mill in which power-looms were to be employed.



POWER-LOOM. (*Cotton.*)

Dr. Cartwright thus lost all hope of deriving any advantage from them, especially on the expiration of his patents. The country was not, however, insensible to the great merits of his invention, for, in 1808, the House of Commons voted him the sum of 10,000*l.*, as some compensation for his outlay and disappointments. In the mean time the power-loom had not been forgotten. In 1798, it was applied at Glasgow to the weaving of cotton fabrics; since which it has undergone a variety of improvements, and, as at present constructed by Messrs. Sharp and Roberts, of Manchester, it is one of the most beautiful machines to be seen in the whole range of the textile manufactures.

Referring to the description of the hand-loom for the principle of plain weaving, it will be sufficient to point out the arrangement of the most important parts of the power-loom as shown in the accompanying cut,

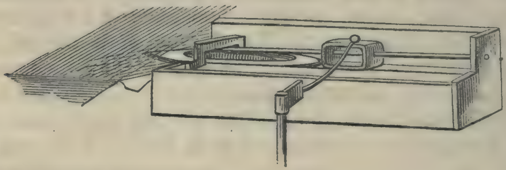


PRINCIPAL PARTS OF A POWER-LOOM.

divested of the frame-work and other parts for communicating motion. The warp is wound round the beam (A), passes up over a roller (B), and is then carried through two healds (D E), which form the shed for the passage of the shuttle (F), which is driven along the shuttle race by a sort of hammer, worked by

a lever moving through a small arc of a circle. The finished cloth (G), kept stretched by the temples (H), is shown, as well as a finished portion wound upon the cloth-beam (I).

It will be understood, then, that when such a loom is properly mounted, five distinct actions are performed entirely by steam-power. 1. It raises and depresses the alternate threads of the warp, so as to form the shed. 2. It throws the shuttle. 3. It drives



THE SHED.

up each thread of weft with the batten. 4. It unwinds the warp from the warp-beam. 5. It winds the woven material on the cloth-roller. In the most improved power-looms there is a sixth action, which is perhaps the most beautiful of all. It is a contrivance for stopping the loom in case the weft-thread breaks, or when the cop contained in the shuttle is run out.

Power looms are usually contained in one large room, or "shed," as it is called, on the ground floor. This room is one of the most impressive sights in the manufacturing districts. In Mr. Orrell's mill, at Stockport, the writer visited a room containing 1306 power-looms, all of which were at work at the same time, producing so overpowering a sound that it was scarcely possible to hear any one speak. These looms are attended by women and girls, whose duties are merely to see that the work goes on properly, to supply the spindle of the shuttle with fresh cops when required, and also to adjust the temples from time to time as the woven fabric becomes wound upon the cloth beam. One woman, assisted by one girl, is thus able to

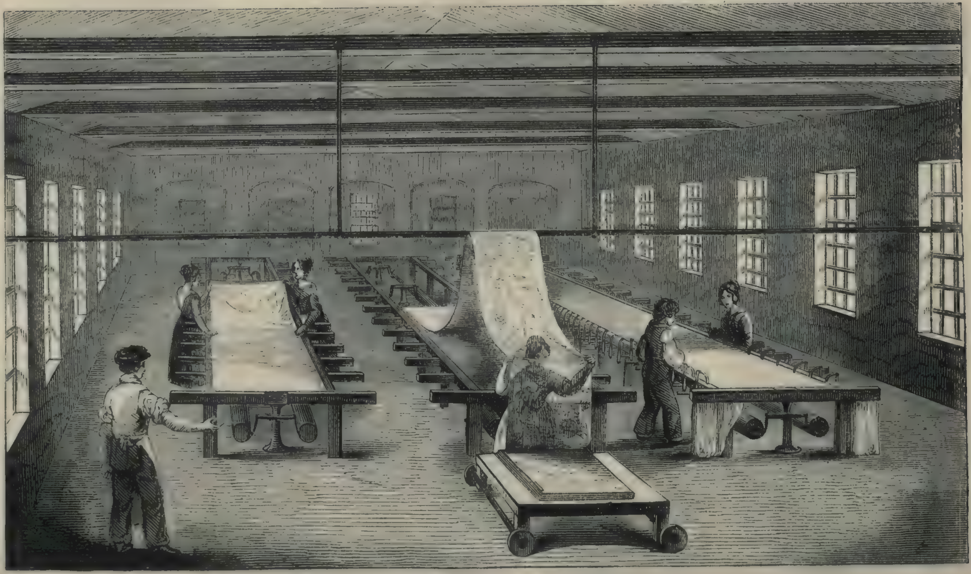
attend to four looms; or one woman alone can take care of two. There is also an overlooker, an experienced man, who has the care of seventy looms, whose business it is to correct any defects in the machinery, which the women are not expected to understand, as also to see that every thing goes on properly. The length of calico woven at each of these looms is variable: in some cases, 600 yards of warp are formed into 10 divisions; in other cases, the divisions run from 25 yards to 70 yards each. When the piece is complete it is carried by the female attendant to a "taking-in room" and examined; any flaws in the piece are entered in a book against the weaver's name; a mark is then made on a tally, which she carries about with her; and this goes to form part of her week's earnings.

The frontispiece represents the interior of Messrs. Ackroyd's power-loom shed at Halifax: at the time of the writer's visit it contained 816 looms arranged in seventeen rows, 48 in each row. The appearance of this room is even more striking than that at Mr. Orrell's mill, on account of the variegated display of beautiful colours and patterns of the goods under process of weaving. A large proportion of the looms are surmounted with the Jacquard apparatus, in which case the looms are so arranged that one set of cards is made to serve two looms. It is interesting to walk from loom to loom and watch the pattern growing, as it were, under the eye, with a beauty and precision almost rivalling that of nature. There we see the gay ponchos, for the South Americans; figured jackets, for the Chinese; and beautifully-coloured stuffs, for various markets of the world. It is a singular example of English enterprise to witness the production, in Yorkshire, of articles of clothing for the natives of the most distant regions of the globe. As soon as a want is known, the skill, capital, and energy of our manufacturers are excited to supply it. The captain of a merchant-ship brings home from China a jacket of native manufacture, such as is very commonly worn in that country. In a few weeks,

or months, a cargo of such jackets, of various colours and patterns, preserving, however, the style of the model, are on their way to China, where they are sold at a lower price than the native weaver can produce them. The merchant receives native productions in return; so that if the poor native weaver has not so much employment at his loom, he has a chance of benefiting by the increased demand for labour consequent on the increased demand for those articles which his country especially produces.

In England, the introduction of the power-loom has had a similar effect on the hand-loom weaver. In one of the Reports of the Parliamentary Commissioners for 1840, it is remarked by Mr. Hickson:—"The trade of hand-loom weaving is not only incapable of improvement, but of remaining in its present state. The best friends of the weaver are those who would advise and assist him to transfer his labour to other channels of industry. If he cling to the hand-loom his condition will become worse from day to day. A few of the more skilled class of weavers may indeed maintain their position, but the fate of the many (unless their intelligence and foresight avert it by change of occupation) is decreasing employment, decreasing wages, and ultimate destitution."

It is difficult to estimate the number of power-looms at work in Great Britain and Ireland at the present time. It was calculated, about ten years ago, that there were at that time 85,000 power-looms in England, and 15,000 in Scotland, while there was no proof that the number of hand-looms had diminished. About the year 1833 the number of hand-looms was calculated at between two and three hundred thousand. Up to that date, weaving by power was chiefly confined to calicos and fustians, but it has since been gradually extended to other fabrics.



DRYING ROOM—(*Muslins.*)

THE

MANUFACTURE OF WOVEN GOODS.

PART II.

THE processes by which cotton, flax, and wool are spun into yarn, and woven into cloth, have been described in former treatises. The woven material is submitted to a variety of operations according to the use to which it is intended to be applied. Calico, muslin, and other cotton fabrics, intended to be sold in a white state, require *bleaching*;* coloured goods must be *dyed;* and pattern goods *printed.* Indeed, the better descriptions of printed cottons require all three processes. Linen goods seldom require more than bleaching; but woollens have to go through a number of processes before the cloth is fit for the market.

HISTORICAL NOTICE OF BLEACHING.

THE art of bleaching seems to have been known to the ancients, especially the Egyptians, among whom white linen was a common article of clothing. Of the Egyptian method of bleaching nothing is known with certainty, but it probably consisted in nothing more than exposing the fabrics to air, light, and moisture.

Until within a century the art of bleaching was scarcely known in Great Britain. During many

* From the French *blanchir,* to whiten.

years all the brown linen manufactured in Scotland was sent to Holland to be bleached. The principal Dutch bleaching-grounds were in the neighbourhood of Haarlem, and they owed their reputation to some peculiar property supposed to exist in the water. After some preparatory processes the linen was removed to the bleaching-grounds, spread out on the grass and sprinkled with pure water several times a-day. In the course of several months' exposure to air, light, and moisture, the goods became bleached. Goods sent to Holland in March were usually returned in the following October; but if not sent till the summer, they were not returned until the autumn of the following year. It is curious that these linens were named after the country in which they were bleached, and not after that in which they were manufactured; they are still known in commerce by the name of *Holland*.

Several attempts were made to introduce the Dutch method of bleaching into this country. In 1749 an Irishman established bleach works in the north of Scotland, and after many failures he succeeded, but the process was still very tedious. The cloth was steeped in alkaline leys for several days; it was then washed clean, and spread upon the grass for some weeks. This *bucking* and *crofting*, as they were called, were repeated alternately five or six times. The cloth was next steeped for some days in sour milk, washed clean, and again crofted. These processes were repeated until the linen was sufficiently white; the strength of the alkaline ley being diminished every time.

By this method, bleaching was not only costly from the length of time which it occupied, but also from the large extent of grass-land which it required. Besides this, the exposure of the cloth was a great temptation to dishonest persons, and the means taken for its protection served to multiply capital punishments, placed deadly weapons in the hands of un-

skilful persons, and led to a dangerous extension of man-traps and spring-guns.

The first improvement which was made in this old Dutch method of bleaching consisted in employing, instead of sour milk, water acidulated with sulphuric acid; the advantage of which was, that a souring occupied only from twelve to twenty-four hours, instead of from six to eight weeks. The bleaching process was thus shortened from eight months to four, which was of course a great advantage to all parties concerned.

But the most important improvement in the art was made by Berthollet, a French chemist, in 1785, in repeating some experiments on a new chemical body, now known by the name of *chlorine*, which had been discovered by Scheele, a celebrated Swedish chemist, in 1774. Berthollet found that it possessed the valuable property of destroying vegetable colours, and this led him to suggest its application to bleaching. It was found to answer the purpose admirably. In 1786 Berthollet showed the experiment to Watt, who was then in Paris, and on his return to England he commenced a practical examination of the subject. In the following year Professor Copland of Aberdeen being at Geneva, M. de Saussure showed him this bleaching property of chlorine, and on the return of Mr. Copland to Scotland he repeated the experiment before some eminent bleachers in his neighbourhood, who immediately adopted the method in their works. According to Mr. Parkes, they were the first to do so, but this is doubted by several writers on this subject. One of the first results of Watt was to bleach fifteen hundred yards of linen by the new process in the bleach-field of his father-in-law, Mr. Macgregor, near Glasgow, and the latter was so well satisfied with the process, that he resolved to continue it at his works.

Thus, through the exertions of scientific men, the attention of bleachers, both in Great Britain and

in France, was fairly called to the application of chlorine to bleaching; but one of the great difficulties in the way of its introduction was the very disagreeable and noxious odour of the gas, which rendered it highly injurious to the lungs of the men who had to inhale it. Besides this, the texture of the cloth was injured when the solution of chlorine was made too strong. Berthollet endeavoured to remove the noxious smell of the solution without destroying its bleaching property by adding potash to the water, by which means a much greater quantity of gas was absorbed; and the liquor could then be diluted with a considerable quantity of water without immediately losing its bleaching quality. It did so, however, after a time, in consequence of certain chemical changes produced in the solution. Mr. Henry, of Manchester, substituted lime for the potash in a peculiar way. The goods to be bleached were passed, by means of a winch, through a stratum of thin cream of lime contained in an air-tight chamber—and immediately on quitting the lime they were exposed to an atmosphere of chlorine. A chloride of lime was thus formed upon the cloth, which, however, was found in some cases to act injuriously.

Other attempts were made to attain the desired object, but they are all now forgotten in the brilliant success of Mr. Tennant, of Glasgow. He discovered a method of making a saturated solution of chloride of lime, which was found to be perfectly successful, and has, indeed, been of immense value to the manufactures of this country. In 1798 Mr. Tennant patented his invention, but the patent being immediately infringed, an action was brought against a bleacher for the recovery of damages. The defendant was supported by a combination of the Lancashire bleachers; and, on the trial, the defence was, that lime had been previously used in bleaching, and that consequently the invention was not new. It is scarcely necessary to say that this compound of chlorine and

lime, the subject of the patent, was new; its application to bleaching being the result of some years of anxious and laborious investigation on the part of Mr. Tennant. However, he lost his cause, and his invention became public property; but, with true courage, he continued his investigations, and succeeded in inventing a method of impregnating lime in a dry state with chlorine, thus producing the *bleaching-powder* which has since become so celebrated. It is prepared in a stone chamber, eight or nine feet high, built of siliceous sand-stone, having the joints of the masonry secured with a cement composed of pitch, resin, and dry gypsum. A door is fitted into it at one end, which can be made air-tight by strips of cloth and clay. A window at each side enables the workman to judge how the impregnation goes on by the colour of the gas (which is yellowish green). The lime to be impregnated is contained in a great number of trays, eight or ten feet long, two feet broad, and one inch deep. These trays are piled, one over another, to the height of five or six feet, and are kept about an inch asunder by means of cross-bars.

The materials employed in generating chlorine are common salt, black oxide of manganese, and sulphuric acid. The chlorine is furnished by the common salt only; (which is a compound of chlorine and the metal sodium;) the use of the other ingredients being merely to assist in decomposing the salt. About ten cwt. of salt are mixed with from ten to fourteen cwt. of manganese, and then introduced into a large leaden vessel of a nearly globular form. This vessel has an outer casing of iron, with an interval between the two, into which steam is admitted for the purpose of communicating heat. From twelve to fourteen cwt. of sulphuric acid are introduced in successive portions through a twisted funnel, and the materials are all stirred up by means of an agitator, the handle of which is on the outside. The gas, as it escapes from this vessel, is received into a leaden cylinder, where

it is passed through a small quantity of water; after which, it enters by a leaden pipe in the top of the ceiling of the stove-room, and being heavier than the atmospheric air, it falls slowly down, diffusing itself through the chamber, and gradually combining with the lime. About four days are required to complete the process; but at the end of two days it is suspended, and a workman enters the chamber and thoroughly rakes up the half-formed chloride, so as to expose the particles of lime which have not yet absorbed the gas. The materials in the leaden retort are frequently stirred during the process, and when all the chlorine is extricated, sulphate of soda and sulphate of manganese remain; the former of which is economically applied to the production of carbonate of soda.

Fortunately for Mr. Tennant his second patent was not contested, but still he laboured under great disadvantages. The duty on common salt in Great Britain was 7*s.* 6*d.* per bushel, while in Ireland the manufacturers obtained it duty free; and as this patent did not extend to Ireland, manufactories of dry chloride of lime were established in that kingdom; but Mr. Tennant's methods were so superior, that he was able to compete with the Irish manufacturers in their own country. In 1815 the duty on common salt used by the bleachers was taken off, and they were thenceforth allowed to use it duty free. The consequence was, that the consumption of chloride of lime was enormously increased, and the art of bleaching arrived at a perfection which is truly astonishing compared with its former rude and slow results. As an example of the rapidity of the process it is stated, that a bleacher in Lancashire received fourteen hundred pieces of grey muslin on a Tuesday, and on the Thursday immediately following they were returned bleached to the manufacturers at the distance of sixteen miles, and were packed up and sent off on that very day to a foreign market.

BLEACHING OF COTTON GOODS.

Most of the bleach-works in Great Britain are situated in Lancashire, and in the neighbourhood of Glasgow; and as the various processes require an abundance of pure water, the works are usually situated near some copious stream. The writer was allowed to visit the works of Mr. Bridson, near Bolton, from which drawings were made for the accompanying engravings.

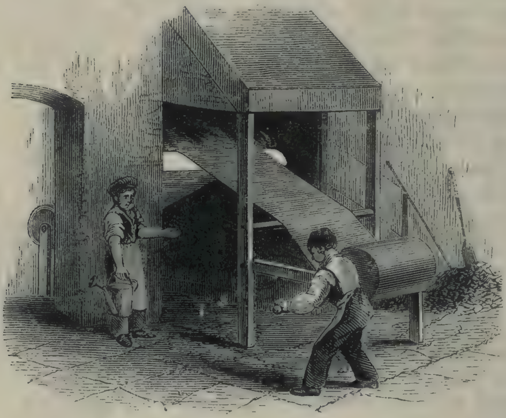
The object of bleaching is to remove from the goods all those substances which prevent it from appearing of a pure white. The fibres of cotton are covered with a resinous matter, which interferes with its absorption of moisture, and also with a yellow colouring matter which seems to be confined to the surface of the fibres, and to have no influence on their strength, for the yarn is found to be as strong after it has been bleached as before. In some cottons its quantity is so small that it would be unnecessary to bleach them before dyeing, were it not that they acquire certain impurities in the processes of spinning and weaving. The weaver's dressing of paste must be removed, and, together with it, a quantity of rancid tallow, or butter, which the weaver sometimes uses to soften the dressing when it becomes dry and stiff. There are also certain soapy and earthy substances, and the dirt of the hands, which must all be removed.

When the goods are received at the bleach-works, the first thing to be done is to stamp the proprietor's name upon the end of every piece. This is done with a wooden stamp, moistened with coal tar; and the impression is not removed in the subsequent operations, but may be got out with soap and hard rubbing. In some cases the pieces are marked at the corner with a needle and thread.

Then comes the remarkable process of *singeing*, which is analogous to the *gassing* of thread, described

in a former treatise, and the object is the same; namely, to burn off a fibrous down or nap on the surface, the presence of which would either injure the appearance of the goods, or prevent them from receiving the dyes properly.

This process is usually conducted in an out-house.



SINGEING CALICO.

A number of pieces of cloth are fastened together at the ends by means of long wires or needles, and then wound upon a cylinder, the axis of which is furnished with a winch. The cloth is then drawn over a red-hot half-cylinder of copper, three-quarters of an inch thick, placed horizontally over the flue of a fire-place, situated immediately at one end of the bar. As soon as the cloth has passed over the ignited bar, it passes over a metal roller, which plays in a trough of water. The cotton is generally passed three times over the bar, with considerable friction; twice on the *face*—that is, the side which is intended to be printed—and once on the back. In a well-arranged furnace about 1500 pieces may be singed with a single ton of

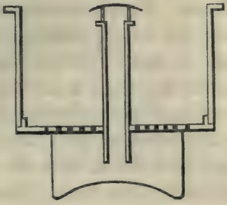
coals, when a copper bar is employed. Iron was formerly used, but copper is found to last ten times as long, and to singe nearly three times as many pieces of cotton with the same consumption of fuel. The cotton is generally wound from one roller over the heated bar, to another roller on the other side of the furnace, a swing frame being conveniently situated for raising the cloth, at any moment, out of contact with the ignited metal, and water is at hand in case of accident to the goods, which, however, is extremely rare. The process is a surprising and beautiful one to look at, but it cannot be enjoyed long on account of the very pungent acrid fumes, produced by the weaver's dressing coming in contact with the hot metallic surface. By this operation the surface of the calico becomes browned so as to resemble nankeen. A gas flame is also sometimes used for the singeing of woven goods as well as thread; and in the case of such delicate fabrics as muslins and bobbin-net lace, it answers the purpose much better. The flame issues from numerous perforations through the upper surface of a horizontal tube, and the cloth to be singed is drawn over the flame by rollers, with a rapidity suited to the texture of the goods. The flame is drawn up through the web, by placing immediately over the gas flame a horizontal tube with a slit made in its lower surface; which tube is placed in connexion with a fan, or some other apparatus, for drawing the air from it, thereby increasing the draught of the flame. This ingenious contrivance is by Mr. Samuel Hall, of Basford, and its value will appear from the fact that a farthing is now paid for a quantity of work which, before its introduction, amounted to a shilling.

The cloth is next steeped for twelve or fourteen hours in a cistern of water. If the cloth were folded or rolled up before being thrown in, the water would not be able to penetrate it throughout; each piece is therefore pulled out into a band, then folded loosely, and tied up into an irregular bundle, and fixed with a

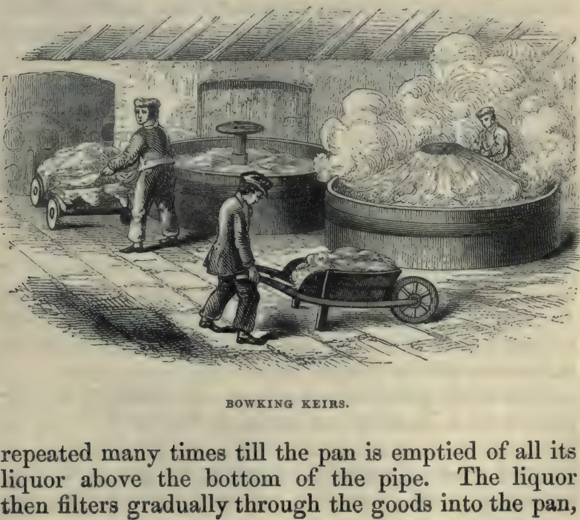
noose at the end. When completely soaked, they are washed in a machine called a *dash* or *wash-wheel*, which is a cylindrical box revolving on an axis, containing four divisions, with an opening in each, into which two pieces are put. Abundance of water is admitted from behind; the cylinder is made to rotate rapidly; and the knocking of the pieces, as they fall from one division to another, constitutes the washing. The dash-wheel is allowed to revolve for five or six minutes, the object being to remove as much of the dirt and weaver's dressing as is possible by water

DASH-WHEELS.

only; but as the grease cannot be removed without some kind of alkali, and lime being the cheapest that can be used for the purpose, the pieces are next boiled with lime in a large circular boiler or keive, called in Lancashire a *bucking or bowking-keir*, and also a *puffer;* the construction of one of these keirs will be best understood from the accompanying section, and its appearance from the sketch. It consists of two parts—a pan of wrought-iron set in brick-work, on which the fire acts, and the upper part of cast-iron



for containing the goods. The two parts are separated by a cast-iron false bottom. In the centre is an iron pipe, furnished with a curved cover. The liquor in the pan, from the pressure of the cloths above it, does not boil till considerably above boiling point; the liquor boils first in that part of the pipe where the pressure is less than it is in the pan; a mixture of steam and water is formed there, which rushes up the pipe, and is reflected back by the cap upon the cloths, drenching them thoroughly with the hot alkaline liquor; this makes room for another portion of the heated liquor, which, rising into the pipe, boils and escapes at the top as before; and this action is



BOWKING KEIRS.

repeated many times till the pan is emptied of all its liquor above the bottom of the pipe. The liquor then filters gradually through the goods into the pan,

where it is again heated, and rushes up the pipe as before. In preparing a keir, one pound of lime is used for every thirty or forty pounds of cloth. The lime is mixed with water in a separate vessel, and passed through a sieve. A layer of pieces of cloth is deposited in the boiler, and over it is spread a portion of thin cream of lime; then another layer of goods, then the lime, and so on, until the whole has been put into the keir; the requisite quantity of water is next added, and heat is applied. Two hours are usually required to boil the liquor, and the boiling is afterwards continued for about seven hours.

The cloth is now cleansed from the weaver's dressing, the greasy stains, and the dirt; but, in consequence of a peculiar property lime has in browning certain vegetable colours, the colouring matter of the cotton appears darker than before. It is now fit for *chemicking*, as the treatment with chloride of lime is called; the cloths are therefore again washed in the dash-wheel, in order to remove the dirty lime as completely as possible. The bleaching is carried on in stone vats, over the centre of which a perforated trough is suspended, and the solution is pumped many times into this trough, from which it pours down over the goods. This action is continued about six hours. Every pound of cloth requires about half a pound of good average chloride of lime, mixed in about three gallons of water. When the chloride of lime-steep is too strong, it sometimes makes small holes in the calico, just as if they had been cut out with a punch, especially in the borders or thicker parts of the goods. When the cloth is washed from the solution of the chloride, it is of a light grey colour, not quite white, but much whiter than it was.

The next process is *souring*. A quantity of sulphuric acid is added to water sufficient to make it sour, but not at all corrosive. In this the cloth is steeped for four hours; the action of the acid is to remove a small portion of oxide of iron always con-

tained in unbleached cloth, and also the lime of previous operations. When taken from the acid it is again washed, and its appearance is now much improved, but it is not sufficiently bleached. It is next boiled for eight or nine hours in a potash or soda ley; then washed at the dash wheels; again immersed in a solution of bleaching powder, two-thirds of the strength of the first solution; here it remains for five or six hours; it is then soured as before, for two, three, or four hours, according to the quality and colour of the cotton, and it at length comes out quite white. The cloth is carefully washed twice, in order to remove every trace of sulphuric acid, which, if left in the cloth, would corrode and destroy it, especially when exposed to the action of heat.

The foregoing account of bleaching applies to cotton shirting, and the better descriptions of cotton fabrics that are to be printed on. The processes are modified for different descriptions of cotton and linen goods; while for wool, they are, for the most part, quite different, as will be noticed presently.

The loss of weight in bleaching fine cotton cloth is nearly ten per cent. Of this, one-half is the weaver's dressing, so that the real loss is not much more than five per cent. In coarse cotton goods the loss is greater.

The theory of bleaching is not well understood. It is supposed, however, that whether the bleaching be performed through the agency of air and moisture, or of chlorine, the real bleaching agent is oxygen; which, by uniting with the colouring matter of the fabric, renders it soluble in water, or in a weak acid solution. The bleaching power of dew and of rain-water is referred to the excess of oxygen which they contain. Perfectly dry chlorine scarcely bleaches at all, but when dissolved in water, its bleaching power seems to arise from its decomposing a portion of the water, the oxygen of which unites with the colouring matter.

BLEACHING OF LINEN.

THE processes employed for bleaching linen are similar to those for cotton, but are continued for a much longer time, on account of the firmer hold which the colouring matter has on flax. The boiling in an alkaline ley, and the steeping in chloride of lime, are repeated three or four times. Linen is also sometimes exposed upon the grass to the sun for some weeks, although this is not essential. The loss of weight in bleaching is about one-third of the whole weight of the goods.

The colouring matter of flax does not appear to be chemically combined with the fibrous threads until the plant is steeped in water, in the process of retting, in order to separate the woody fibre. Hence, to save the expense of bleaching, it has been proposed, instead of steeping the plant, to dry it, and then beat off the woody fibre by means of wooden mallets. The flax can then be bleached simply by washing in water.

BLEACHING OF WOOL.

THE method of cleaning or scouring wool has been described in the treatise on the Manufacture of Woollen Yarn. The oily substance or yolk of the wool has the property of combining with a species of clayey earth called *fuller's earth*, which, for the sake of economy, is used by the fullers instead of soap. The brilliant white appearance of wool which is required in some manufactures, is produced by the vapour of burning sulphur, or by steeping in a solution of sulphurous acid.

The usual method of *sulphuring*, as it is called, is to expose the wool, in a very close apartment, to the vapour of burning sulphur. The goods are hung on

poles, and are so disposed that the vapour can readily pass between the pieces. When the chamber is filled, a quantity of sulphur is placed in very flat and broad dishes, and set fire to, and allowed to burn away gradually in the chamber, every aperture by which the vapour could escape being carefully closed. The acid vapour penetrates every part of the cloth, destroys the colouring matter, and thus completes the bleaching; which occupies from six to twenty-four hours. The sulphurous acid vapour leaves a rough harsh feel upon the wool, which is got rid of by washing in water slightly impregnated with soap.

One hundred pounds of raw wool, when completely scoured and bleached, will not yield more than thirty or forty pounds fit for the manufacture of cloth.

CALENDERING.

When cotton or linen goods are bleached, a number of finishing processes are usually adopted, in order to improve the appearance of the goods, or to prepare them for the calico printer, by making the surfaces level, compact, and uniform. These processes are mostly included in the term *calendering*, said to be a corruption of *cylindering*, the goods being passed between cylinders or rollers.

When the pieces of cloth are taken out of the dash-wheel after being finally washed, they are crumpled together, and frequently entangled in irregular knots, which, if allowed to remain, would injure the calendering machinery. Each piece is therefore drawn out to its full extent, by an ingenious contrivance. Immediately before a pair of rollers is a water cistern, the top of which is on a level with the floor of the room; and this cistern is kept constantly filled. The cloth is made to pass over this water on its way to the rollers, and in doing so, the force necessary to drag it through the water

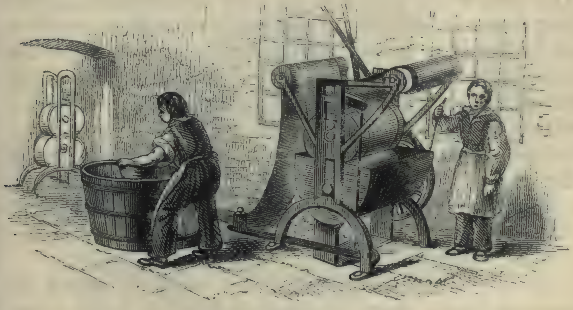
stretches out the piece, and removes all knots and wrinkles. In this way, the cistern of water is made to serve the purpose of two pair of hands; for, as two pieces of cloth pass through the rollers at once, one person would, but for this contrivance, be required to unfold each piece.

The cloth is still wet, and crumpled together: each piece has, therefore, to be pulled out to its breadth, and the edges beaten out. The latter is done by knocking them against a smooth beating-stock, which also removes all folds and wrinkles. The pieces are then stitched together, end to end, by women, with a sailor's needle, and they are now ready for the mangle.

The mangle used in calendering does not at all resemble the domestic mangle, which is probably familiar to the reader. It consists of a number of rollers, fixed in a strong upright frame; the rollers being forced together by levers, to which a considerable weight is attached. The rollers must be turned quite true, so as to be perfectly cylindrical. In the mangle at Bolton, the two bottom rollers were grooved; the grooves gradually spreading from the right to the left, on either side; the effect of which was to remove creases by spreading out and extending the cloth in passing between them; above these were three smooth rollers, two of wood and one of brass, in passing between which the water is equalized throughout the whole piece, the threads flattened, and the cloth stretched. It is then wound upon a roller, ready to be starched.

The starch used in calendering is made of flour, wheat starch being too expensive: but as the gluten of wheat renders it unfit for the purpose, the texture of the gluten is destroyed by fermentation. The flour is mixed with water in the proportion of one pound of flour to the gallon of water, and, when properly fermented, the whole is passed through a sieve, for the purpose of separating the bran. The starch is then

boiled, a small quantity of indigo is added, to give it a blue colour, and it is afterwards mixed with such a quantity of water as will give to the goods the necessary degree of stiffness. Starch is often thickened with an equal bulk of porcelain clay, or with equal parts of clay and calcined plaster of Paris; the effect of which is to add considerably to the apparent strength and thickness of the cloth. It has been observed, by Dr. Thomson, that "this method of thickening was undoubtedly intended at first as a fraudulent method of making the purchaser believe that the cloth was much stouter and thicker than it really was. But it has been so long practised, and is now so universally known, that all purchasers must be aware of it, and of course not in any danger of being deceived. But it certainly serves the purpose of making the goods appear much more beautiful, and of a stouter fabric to the eye; and, as long as they continue unwashed, they are really stronger than they would be without this artificial dressing. So far it is beneficial; and as it does not enhance the price, the purchasers have no reason to complain of imposition."



STARCHING.

The *starching machine*, also called the *stiffening mangle*, is formed of rollers of brass and wood, pressed together by levers, loaded more or less so as to regu-

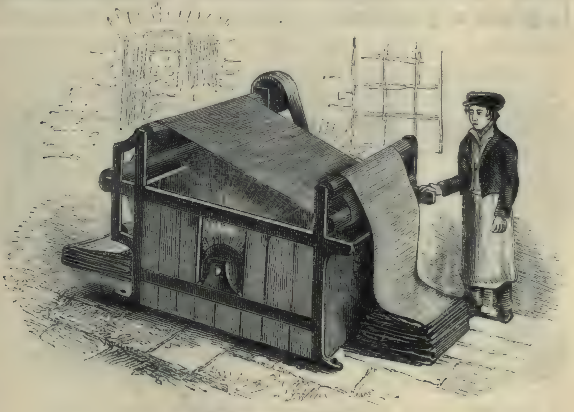
late the quantity of starch intended to be left in the cloth. The starch is contained in a trough, into which a roller dips, and the cloth in passing under this roller becomes filled with starch, the superfluous part of which is pressed out again by the upper rollers, and falls into the trough. The piece then passes over a roller, and is removed for the next operation, which is *drying.*

Strong goods are dried upon large iron cylinders, which vary from eight to eighteen feet in diameter, and are heated by being filled with steam. The more delicate fabrics, such as muslins, are dried on elongated frames, in a room heated by steam. The frontispiece represents the interior of one of the drying rooms at Mr. Bridson's bleach-works at Bolton, in which, at the time of the writer's visit, muslin was being finished. Each piece of muslin, about twenty-five yards in length, was brought in by young women, and extended along the frame, the selvages being confined by a number of iron clamps covered with flannel; the two opposite sides of the frame are then driven further asunder by means of a screw which connects them, by which the muslin is stretched to its full breadth. The people are forced to be very expeditious in putting down a piece, for, if one part dries before another, or before it is properly stretched, the pattern of the muslin becomes crooked, or it will even burst into holes. Two young women can lay down a piece within two minutes, although each has to press down forty-seven clamps. At the average temperature of the room, (which is from 90° to 100°, although it sometimes rises to 110°,) a piece is from ten to fifteen minutes in drying. When dry it is transferred to the making-up room.

Muslin is thus prepared by what is called the *common finish;* there is another kind of finish called the *patent finish,* which is as remarkable in its appearance as in its results. As soon as the muslin is attached to the frame, the two long sides are screwed out, and they are then made to work backwards and

forwards in opposite directions, but in the direction of their length. The piece of muslin is not held by clamps, but by small projecting pins, which are made to pass through the selvage by pressing it upon them with a small wheel, the rim of which is covered with flannel. This is done with great rapidity; and the moment the piece is laid down, the diagonal motion is begun, and continued until the muslin is dry. The effect of this singular method of finishing is to remove the stiffening which the starch would otherwise produce, and to make the muslin clear and elastic, and not liable to form wrinkles when made up into a dress.

Such is the finishing process for muslin. Many descriptions of cotton goods require glazing or *calendering,* properly so called, whereby a polish or gloss is given which makes the surface smooth, compact, and uniform. The goods are first damped, by passing them slowly over a machine, which sprinkles them with water in fine spray, sufficient to enable them to assume the gloss which it acquires by passing through the calender.

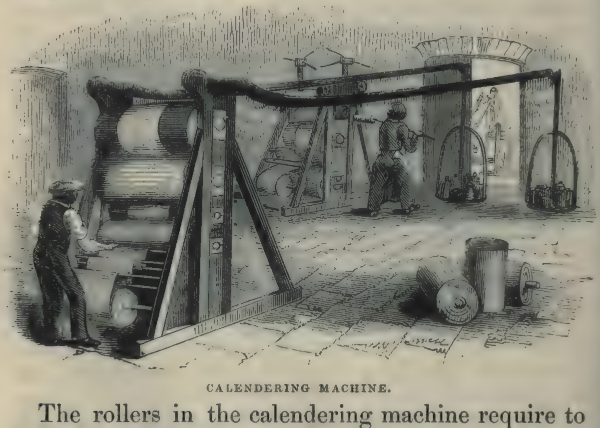


DAMPING MACHINE.

The *damping* or *degging machine,* as it is called in Lancashire, is a box containing a circular brush,

made to revolve rapidly, its points just touching a surface of water which is kept at a uniform height. The goods, dry from the drying-room, are passed over the surface of the box in single folds, by a pair of rollers.

The cloth is then passed through the calendering machine, which consists of a number of rollers, contained in a massive frame-work. The rollers (or *bowls*, as they are called in Lancashire) are connected with a lever, thirty or forty feet long, loaded with weights at the further extremity, by which the rollers can be pressed together with almost any amount of force, by varying which, the texture of the cloth may be made to vary at pleasure. When the goods are passed between smooth rollers, the threads are flattened, and the whole piece assumes a soft and silky lustre, as if it had been ironed. When two folds of cloth are made to pass together through the rollers, the threads make an impression on each other, and assume a wiry appearance, with an intermediate hollow between each. Various degrees of this wiry appearance may be given at pleasure.



CALENDERING MACHINE.

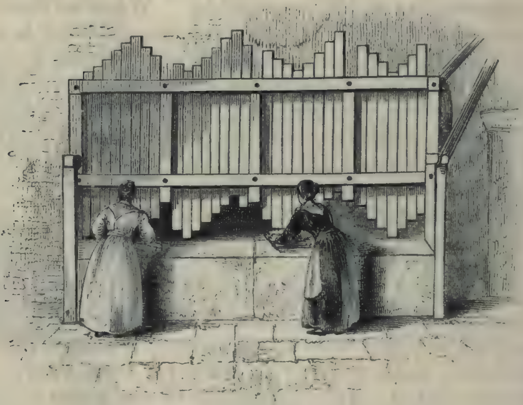
The rollers in the calendering machine require to be made with the nicest care. They are of cast-iron,

of wood, of paper, and of calico. The iron rollers, after being cast, are nicely turned and polished. In each machine one of them is made hollow, for the purpose of admitting steam, or a hot iron rod, when heat is required. The wooden rollers are mostly superseded by those of pasteboard or paper, which have many advantages over wood. A paper cylinder takes a finer polish, does not crack or warp, and, from having a certain degree of elasticity, it gives a more equable pressure on all parts of the cloth than could be obtained from wood. The manufacture of these paper cylinders is a curious art. They are made by placing circular discs of stout pasteboard upon a square bar of wrought iron, which serves as an axis. The discs at the two ends are of cast iron, a little less in diameter than the remainder of the cylinder. These discs being screwed down tight, the cylinder is placed in a stove, and kept, during several days, at as high a temperature as the paper will bear without being charred or rendered brittle. As the moisture is driven off, the paper shrinks, and the screws are tightened, to keep the mass compressed as tightly as possible. When no further diminution of bulk is perceived, the cylinder is removed, and when cool, the pasteboard forms a substance remarkably dense and hard. The cylinder is next turned at a lathe; an operation requiring much labour and patience. The substance is so hard, that tools of very small size must be used, to scrape rather than cut it, and the motion in turning must be very slow. The tools are blunted so quickly, that the turner keeps two men constantly at work in sharpening them.

The calendering machines at Messrs. Goodier's, in Manchester, (from which the drawings for the accompanying sketches were taken,) mostly consisted of five cylinders, each varying in diameter from twelve to twenty inches. In consequence of the great weight of the machines, and the force employed in pressing

the rollers together, this kind of work is carried on in cellars, or at least on the solid ground. Each piece of cloth, after being damped, enters the calender from behind, above the first or uppermost cylinder; it then passes between the first and second; proceeding behind the second, it comes again to the front between the second and third; it then goes between the third and fourth, and is once more carried behind; and lastly, brought in front between the fourth and fifth, where it is received and smoothly folded on a clean board by a person placed there for the purpose: it is then taken away to be made up.

Velvets are stamped with a variety of figures and patterns, by means of embossing rollers of copper, of which a large variety is kept. The water surface is produced by passing the goods in a damp state through the calender, either with hot or cold rollers, plain or variously indented, and sometimes with a slight lateral motion. Jaconets, Irish linens, &c., are watered by means of a beetle, consisting of a number of wooden stocks falling upon a smooth stone surface. Motion



FLAT BEETLE.

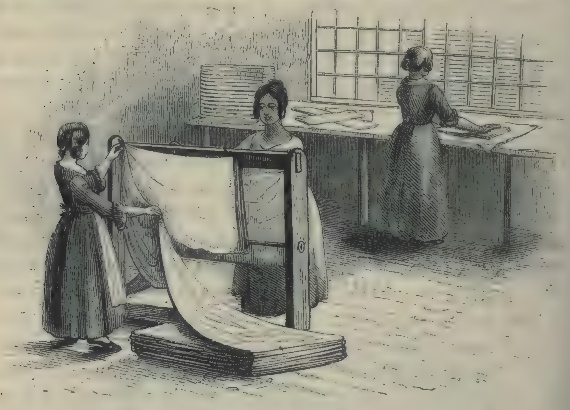
is communicated by means of a horizontal roller behind the machine, from the surface of which project a number of pieces of wood. As the roller revolves, the projecting pieces come in contact with corresponding pieces in the stocks, which elevate them to a certain height, when, escaping from contact, they are allowed to fall by their own weight.

In the making-up room the goods are measured, preparatory to being lapped into rolls or folded into plaits. The measuring is done either at a long table or at the hooking frame. The measuring table is a long smooth plank, with a scale of inches, feet, and yards marked at the side; a man stands at one end of the table with the goods to be measured, and there is a boy at the other end. A length of cloth being spread out, the boy holds its extremity down at a line drawn on the table, while the man, at his end, marks a length of a certain number of yards, usually about five, with a piece of red or white chalk, according to the colour of the goods; the red being used for white stuffs. The boy then draws the cloth towards him, until the chalk mark comes opposite the line on the table, when he stops; the man then makes a second mark, the boy draws the length towards him until this mark gets to the line, when the man repeats the mark, and so on, until the proper length for a piece of goods is run off. Goods for the foreign market are measured by what is called *short stick;* those for the home market by *long stick.* In short stick the yard is made to consist of "35 inches and a thumb," which is, in fact, 36 inches, the usual length of the yard. In long stick the yard contains "36 inches and a thumb," which is equivalent to 37 inches. There is also *middle stick,* containing "35½ inches and a thumb" to the yard, and this is equal to 36½ inches.

At the time of the writer's visit to Messrs. Goodier's calendering works, a glazed printed calico was being measured into pieces of 100 yards, and half pieces of 50 yards. These were then taken to a

rolling machine, and wound upon wooden rollers, and afterwards packed in paper.

The goods that are made up in folds, are measured at the *hooking frame*, which consists of an iron bar, rather more than four feet long, graduated into inches and parts, supported by a frame of wood, and capable of being raised to different heights, according to the height of the hooker, who is usually a little girl. At one extremity of the measuring bar is a



HOOKING FRAME.

sharp projecting needle, which is fixed. A second needle is attached to an iron slide, which moves freely along the bar, but can be fixed at any point by means of a screw. The length of the yard is a variable quantity at the hooking frame as at the measuring table. This being determined for the particular goods to be measured, the hooker hangs the cloth in regular folds upon the hooks, until a sufficient quantity is collected to form a piece, which is then cut off and removed to be made up.

The making up of finished goods for the market is

rather a complicated affair, on account of the great variety of folds in use, amounting to about a hundred. Every one of these has its own peculiar name, such as the "falling lap," the "Wigan way," the "cloth way," the "Preston way," &c. Muslin is made up in "book-folds," in pieces of twenty-four yards: but usually, two half pieces, called "demis," are made up into one book, with yellow paper under the first fold, to show the pattern, and the corners secured with variegated silk thread. Tickets, containing various devices in gold or bronze upon a blue or red ground, are pasted upon each piece, according to the different markets in which they are to be exposed—different tickets being required for different markets. Some of these tickets are very costly, and of large size: those printed in gold costing from 16*s.* to 25*s.* per hundred, while the commonest and cheapest tickets may be had for 2*s.* per thousand. The devices on these tickets are as various as their appearance: they may contain the name, or the crest, or the coat of arms of some Portuguese or Greek merchant: or mottoes in various languages, naming the goods, or assigning some excellent qualities to them: and it is curious that the sale of the goods depends, in great measure, upon these tickets; for if they were absent, the goods, however well prepared, and however excellent, would be slighted. There is no doubt that this system of ticketing gives rise to much deception, the object being to make the goods pass for foreign, or to lead foreigners to suppose that they are the productions of their own country, while, in fact, they are of British manufacture.

When the goods are regularly folded and ticketed, they are placed in a hydraulic press, with a sheet of pasteboard between each piece, and after a certain interval an iron plate is substituted for the pasteboard, to prevent any inequality in the pile. When sufficiently pressed, they are packed up between boards, or in wooden cases, and are ready for shipment.

HISTORICAL NOTICE OF DYEING.

THE art of dyeing, or communicating a permanent colour to textile substances, seems to have been known at a very early period. Jacob made for Joseph a coat of many colours. (Genesis xxxvii. 3.) In the Book of Exodus frequent mention is made of the ornaments for the Tabernacle, as being composed of blue, and purple, and scarlet, and fine linen; and it has been remarked that throughout the Pentateuch those colours are arranged exactly in the same order.* It is also curious, that after a lapse of several centuries which intervened between the period described in Exodus and the time of Solomon, the colours employed in the ornaments for the Temple should be still mentioned in the same order as those of the Tabernacle, except in one instance, where the red is called crimson instead of scarlet. (2 Chron. iii. 14.) There is also a variation in the order in which the colours are named, in the chapter preceding that just quoted, (v. 14.) Solomon having sent to Tyre for coloured linens, the king of that country answered his request by sending him a man skilful to work "in purple, in blue, and in fine linen, and in crimson." The purple mentioned in the Book of Exodus was also probably dyed by the Tyrians. Ezekiel, who wrote about 593 years before the Christian era, in his prophecy against Tyre, says:—"Fine linen, with broidered work from Egypt, was that which thou spreadest forth to be thy sail; blue and purple from the isles of Elishah was that which covered thee." (Ezekiel xxvii. 7.) It is supposed that by Elishah is meant Elis, on the west side of the Greek Peloponnesus. Hence it seems probable, that the Tyrians in Ezekiel's time

* See Exodus xxv. 4; xxvi. 1, 31, 36; xxvii. 16; xxviii. 6, 8, 15; xxxv. 6, 23, 25, 35; xxxvi. 8, 35, 37; xxxviii. 23; xxxix. 1 to 29; and several other places.

drew their supply of shell-fish used for dyeing purple from the coast of Greece.

The Tyrian purple was very highly prized among the nations of antiquity. It is now generally believed to have been obtained from two different kinds of shell-fish, described by Pliny under the names *purpura* and *buccinum;* it was extracted from a small vessel or *sac* in their throats, one drop only being obtained from each animal. An inferior colour was obtained by crushing the whole substance of the buccinum. A quantity of the juice being collected, sea salt was added, and it was allowed to stand three days; after which it was diluted with five times its bulk of water, kept at a moderate heat for six days more, being occasionally skimmed, and when thus clarified, was applied directly as a dye to white wool which had been previously prepared by the action of lime water, or of a species of lichen called fucus. For the finest Tyrian purple, the wool was first plunged into the juice of the purpura, and then into that of the buccinum. No colour was produced until the wool had been exposed to air and light; it then passed through various shades of citron yellow, green, azure, and red, and became, after forty-eight hours, a fine purple. Sometimes the wool was first dyed with a cheap dye, and the cloth received a finish from the precious animal juice. The colours seem to have been very durable, for Plutarch says that the Greeks found in the treasury of the king of Persia a quantity of purple cloth, of a beautiful colour, though it was 190 years old. According to Pliny, a pound of the double dipped Tyrian purple was sold in Rome, in the time of Augustus, for a hundred crowns.* Notwithstanding this enormous price, many of the citizens of Rome wore purple attire, until the time of the emperors, when the use of purple was limited to them. This, of course, greatly diminished the extent of the manu-

* Equal to about £30 of our money.

facture. It continued to languish till the eleventh century, when it became extinct; and the mode of dyeing purple was lost for many ages. It was, however, again revived during the seventeenth century by Mr. Cole, of Bristol, and during the eighteenth century by M. Reaumur, of France; but by this time finer colours had been discovered, and cheaper processes invented.

Dyeing was not much cultivated in ancient Greece: the people of Athens wore woollen garments of the natural colour. The Romans were more attentive to the art, although, in common with most of the useful arts, it was held in too little esteem to be considered worth describing by those competent to do so. Pliny notices the dresses of those who contended in the games of the circus as being green, orange, grey, and white. The art was lost at Rome after the invasion of the northern barbarians, in the fifth century; but it still continued to be practised in the East, and again appeared in Europe about the end of the twelfth century. Florence then became celebrated in the art, and in the early part of the fourteenth century numbered not less than two hundred dyeing establishments.

The number of substances used in dyeing was somewhat limited until the discovery of America supplied Europe with many new colouring materials, such as indigo, logwood, quercitron, Brazil-wood, cochineal, and annatto.

Previous to the introduction of indigo, woad was extensively used for dyeing blue. The ancient Britons, when first invaded by the Romans, are described as having their bodies stained with the colouring matter of this plant. The cultivators of woad in England, and in many parts of the continent, succeeded in getting laws passed in their respective countries against the use of indigo, which in Germany, by a decree of the Diet held in 1577, was declared to be a "pernicious, deceitful, eating, and

corrosive dye." Logwood met with a similar opposition. In the reign of Elizabeth its use was prohibited by very heavy penalties, and all found in the country was ordered to be destroyed; nor was its use permitted in England until the reign of Charles the Second.

It was not till these and similar prejudices were overcome, that the art of dyeing made progress in this country. Several valuable improvements were made, and new processes introduced from abroad, among which may be mentioned the method of dyeing Turkey-red, which is one of the most durable vegetable colours known. It was discovered in India, and afterwards practised in other parts of Asia, and in Greece. About the middle of the last century some Greek dyers established dye-works in France for this colour; and in 1765 the French government caused an account to be published of the method of producing it. The method was not, however, practised in England until the end of the last century, when a Turkey-red dye-house was established in Manchester by a Frenchman, who obtained a grant from government for the disclosure of his process; but his method did not prove very successful. A better process was introduced into Glasgow, by a Frenchman named Papillon; but before this, Mr. Wilson, of Ainsworth, near Manchester, had obtained the secret from the Greeks of Smyrna, and published it.

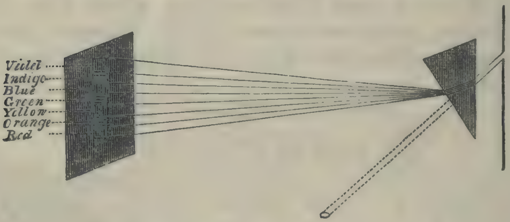
NATURE OF COLOUR.

THE great object of dyeing is to impart a permanent *colour* to textile fabrics; and the methods of doing this are almost as numerous as the colouring matters employed. Most of the colours used in dyeing are of vegetable origin; a few are animal and mineral. The most vivid and brilliant vegetable colours, such as those of flowers and other parts of

plants exposed to the light, are small in quantity, and so fugitive that they are exceedingly difficult to separate. Nearly all the colouring matters of plants which are capable of being isolated, are yellow, brown, and red: the only blue dyes furnished by plants, are indigo and litmus: no black vegetable substance has ever been isolated.

Most vegetable colours are soluble in water. Those which do not dissolve in water are soluble in alcohol, ether, and the fixed oils. Vegetable colours are permanent in dry air, but they gradually fade in moist air, especially under the influence of the solar rays. Acids and alkalies exert a remarkable action upon them,—the blue of most flowers being made red by an acid, and green by an alkali.

Colour is not, properly speaking, a material substance, since it does not exist in the object, but in the light which the object reflects. A ray of white light consists of a number of differently-coloured rays, which may be separated by means of a glass prism. If a sunbeam be admitted into a darkened room through a small hole in the window-shutter, it will form a white spot upon the floor, as shown in the figure; but if the beam be intercepted by a glass



DECOMPOSITION OF WHITE LIGHT.

prism, it will be refracted or bent out of its ordinary course, and produce, not a white spot, but a *spectrum*, or long streak of beautiful colours, which may be re-

ceived upon a white screen. These colours are seven in number, red being at the bottom of the spectrum, then orange, yellow, green, blue, indigo, and violet at the top.

This beautiful experiment was first made by Sir Isaac Newton, who accounted for the production of so many colours from a white sunbeam by supposing that it is actually composed of seven distinct colours, which being mixed in certain proportions, neutralize or destroy each other. In order to account for the decomposition of the sunbeam by the prism, and for the lengthened form of the spectrum, he supposed that each of the seven coloured rays was capable of being bent by the prism in a different manner from the rest. Thus, in the figure, the red is supposed to be less bent out of the direction of the original ray than the orange, the orange less than the yellow, and so on, until we arrive at the violet, which is bent most of all. These views have since been abundantly confirmed; but it has been found that the orange, green, indigo, and violet, proceed from the intermixture, in various proportions, of the *red*, *yellow*, and *blue*,—these latter being the only *primitive* or pure colours in nature; white light may, therefore, be considered as a mixture or combination of these three primitive colours, their exact equilibrium producing an absence of all colour, or white light.

If the coloured rays which have been separated by one prism are allowed to fall upon a second prism, inverted and placed near the first, they become reunited, and again produce white light. But if, in this composition, some of the rays are omitted; or, if the coloured rays are not in proper proportion; the resulting compound will not be white, but light of a certain colour. For example, if the red rays be omitted, the remaining colours will, by combining, form a bluish green. If the orange be separated, the other rays will form blue; if we separate the greenish yellow rays, the rest will form violet; and if we

separate the yellow, or orange yellow, the others will form indigo.

Hence it appears that every coloured light bears such a relation to some other coloured light, that, by uniting the first with the second, white light is reproduced. One of these lights is called the *complement* of the other. Thus, red and blueish green are complementary colours; so are orange and blue; greenish yellow and violet; and orange yellow and indigo. Yellow mixed with red produces orange; blue and yellow form green; blue and red produce violet or indigo, according to the proportion of red to the blue.

The dyer takes advantage of these facts in the production of compound colours. He can produce orange from red and yellow dyes; green from yellow and blue; and indigo or violet from blue and red. But if he attempts to produce white by combining red, yellow, and blue, he will probably obtain a dark brown or black, because the resulting combination does not reflect so much light as the three coloured ingredients separately. There are cases, however, in which white may be produced by the combination of the three primary colours. Certain kinds of goods, after being bleached, always retain a brownish yellow hue; this may be removed, and a pure white be produced, by applying a small quantity of smalts, indigo, orchil, or a mixture of Prussian-blue and cochineal pink. In such cases, the blue, or mixture of blue and pink, unite with the brownish yellow of the goods, and produce white.

Opaque substances which absorb all the three coloured rays, reflect no light, and consequently appear *black*. Those which reflect all the light which falls upon them, are *white*. Those which absorb the whole, or a portion of one of the three primary rays, and reflect the remainder, or absorb unequal portions of each of the three rays, must appear *coloured*. Thus a blue substance reflects only the blue rays, and ab-

sorbs or stifles the yellow and red. A red substance absorbs yellow and blue, and reflects red. Hence, it will easily be seen, that by the absorption in unequal portions, and by the reflection of more or less of the white light, every shade of colour in opaque substances may be produced.

A similar explanation applies to transparent or translucent substances. If we hold up to the light a piece of red silk, the texture of the material allows red only to pass through, and prevents the passage of the yellow and blue rays. A green transparent substance allows the yellow and blue to pass, but stops the red rays.

According to these views of colour, the art of dyeing is said to consist in fixing upon stuffs certain substances which act upon the light in a manner different from the stuffs themselves.

PREPARATORY PROCESSES FOR DYEING.

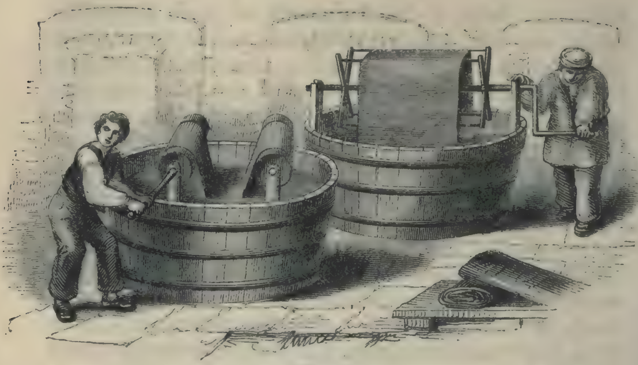
THE processes by which different kinds of textile fabrics are dyed with the same colouring matter, are often very dissimilar, different methods being adopted for cotton, silk, and wool. In order, therefore, to give a general idea of the art of dyeing, it will be necessary to confine our attention principally to cotton; for this requires more numerous and elaborate processes than wool and silk, which receive colour with comparative ease. The writer's information on this subject has been greatly assisted by a visit to the Egerton Dye Works at Turton, near Bolton; the proprietor of which, Mr. Wm. Darbyshire, has kindly allowed drawings to be made to illustrate the following remarks.*

* The writer also desires to express his acknowledgments to Mr. Parnell's excellent scientific Treatise on Dyeing and Calico Printing, contained in his work on Chemistry applied to Manufactures. 8vo. London, 1843.

The dye-house at Turton consists of an immense apartment, which forms the basement story of a large cotton-mill. It is paved with stone, and supplied with a complete system of drainage for carrying off the spent dye stuffs and soiled water which result from each day's operations. On entering this apartment, the visitor is struck with what appears to be the confused assemblage of differently-shaped machines, unlike the sameness which is equally remarkable in the grouping of the machinery of a spinning or weaving-mill. Here are large stone cisterns for bleaching and for washing; dash-wheels, and other wheels, also for washing; vessels containing dye-stuffs, called *dye-becks;* others, containing soap and water, called *soap-becks;* mangles for rolling the cloth; others furnished with brushes for laying the fibres all in one direction; squeezing rollers for pressing out the water from the goods; and a curious machine for drying the goods by centrifugal force, which will be noticed hereafter. Under the feet are streams of all colours threading their way through the dregs of other spent dye-stuffs which had been thrown away some time before. Occasionally may be seen a vessel containing a liquid which is boiling without any visible source of heat. Heat, however, is supplied by the introduction of steam from a large boiler in a neighbouring apartment. There are also conveniences for supplying water to almost any amount. In some dye-works the daily consumption amounts to from 600,000 to 800,000 gallons. The purity of the water is of the utmost consequence; distilled or rain-water, or that of an Artesian well, is generally better than spring or river-water, which usually contains lime, and this exerts an injurious action on the dye-stuff: there is also a small quantity of iron in most spring and river-water, which gives a brown tinge to goods washed in them.

Adjoining the dye-house is a room for storing, grinding, mixing, and dissolving the various dyeing

materials, salts, &c. Infusions of such drugs as fustic, sumach, and logwood, are made in tubs or vats; 50lbs. of the drug being mixed with 200 gallons of boiling water. Some of the vats are furnished with a perforated false bottom, to separate the solid matter from the infusion, and the latter is conveyed to vats in the dye-house. A decoction of sumach is obtained by boiling it in an open copper boiler, which is the vessel usually employed for decoctions. For some delicate dyes, where a steam heat is applied, vessels of tinned iron or copper are used. Different vegetable colouring matters vary so much in their properties, that few general observations apply to all of them. If the substance be very soluble, its solution is usually made in cold water: if only slightly soluble, heat is applied provided the colour is not injured thereby. When the solution is required to be highly charged with colour, a portion of the water is driven off by heat; but this requires caution, as many vegetable colours are injured by long boiling. If the goods are not kept in constant motion when in the dye-beck, the infusion should be previously filtered, or the clear part poured off, to separate insoluble woody matters. In some cases a coloured infusion is obtained by inclosing the colouring substances in bags, which are removed from the liquid when sufficient colour is imparted. If, however, the goods are kept in continual motion while in the dye-beck, as is almost always done with cottons, the separation of the insoluble matters is immaterial. The vegetable material is commonly introduced in a state of coarse powder into the dye-beck containing cold water; the pieces of cotton are put in at the same time, and the temperature of the liquid gradually increased by the introduction of steam by a pipe connected with the boiler. Motion is given to the goods in the dye-beck by a winch or reel placed horizontally over the middle, as shown in the cut, so



DYE-BECKS.

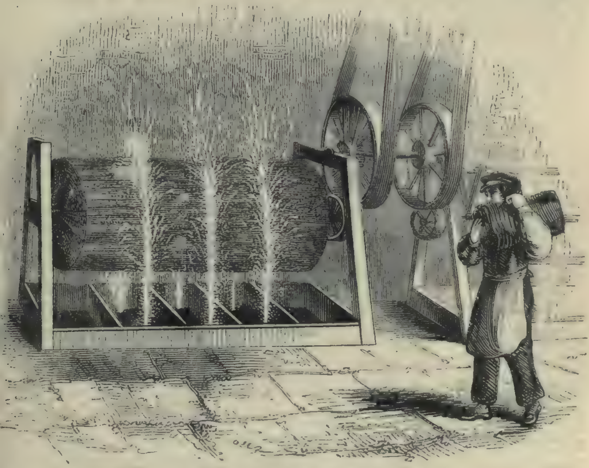
that the cloth may be made to descend into either compartment of the dye-beck by the rotation of the wheel. By another arrangement, shown in the cut, the cloth is wound from one roller to another, passing in the interval through the dye under a roller placed at the bottom of the dye-beck.

Vegetable and animal fibres generally imbibe colour much more readily before they are spun into yarn, and the yarn can be dyed more readily than the woven cloth. Wool in flocks, after having been washed, digested in alkaline ley, and bleached, takes more colour than when in its spun or woven state. This seems to arise from the comparative difficulty which the solution of the colouring matter has in penetrating the fibres. The colour of the interior of a piece of thick woollen cloth dyed in the piece, is often less intense to the eye than the colour of the exterior. Piece-dyeing is, however, less expensive than dyeing wool in flocks or in yarn, as less of the material is wasted, and the colour is not exposed to injury during the operations of spinning and weaving.

Cotton goods are usually dyed in lengths of from 100 to 120 yards, several pieces being joined together

to make such a length. The cloth is first singed and then bleached; both these operations being performed at the dye-works; the bleaching, however, is much less elaborate than that already described, an inferior white answering for some colours, and, where a pure white is desirable, the bleaching is entrusted to the professed bleacher.

After the goods are singed, they require a thorough washing, which, at the Egerton Dye Works, was performed by wrapping them loosely upon a wheel, which being made to revolve rapidly, the water let in upon the goods, presented an appearance which the artist has attempted to represent in the annexed cut.



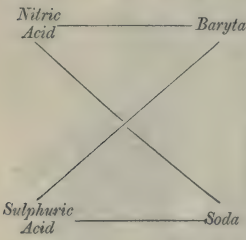
WASHING BY STEAM-POWER.

DYEING.

The art of dyeing depends greatly for the success of its operations upon those relations between various substances, which are known to the chemist under

the name of chemical affinities or attractions. For example, camphor can scarcely be said to dissolve in water, but it is perfectly soluble in alcohol or spirits of wine: hence it is said that camphor and water have little or no affinity for each other, but that camphor and alcohol have a strong affinity. But if to the solution of camphor in alcohol water be added, the alcohol will immediately loosen its hold of the camphor, and unite with the water, and the camphor having nothing to dissolve it, will reappear in its solid state, forming what is called a *precipitate*. In this case, it is said that a stronger affinity exists between water and alcohol than between alcohol and camphor.

The above is a case of simple attraction or affinity, in which one body separates another from its combination with a third. Let us now take an example of what is called *double decomposition*, which bears more immediately upon our present object. Nitrate of baryta and sulphate of soda are salts soluble in water; but if these solutions be mixed together, two new compounds will be formed, one of which is soluble, and the other not.



The change that takes place will be understood from the above diagram, in which the substances, before being mixed, are shown in the parallel lines, and after mixture, in the diagonal lines. The nitric acid quits the baryta to unite with the soda, forming nitrate of soda; and the sulphuric acid quits the soda to unite with the baryta, forming sulphate of baryta, which is an insoluble precipitate.

One of the simplest methods of dyeing depends upon such a case as this. The colouring matter is produced in or upon the cloth in the form of an insoluble precipitate, by mixing two solutions, in nei-

ther of which does the colour exist separately. The advantage of this method is, that the cloth can be impregnated with one solution, and then, upon immersing it into the other, the insoluble colouring matter is formed within the elongated cell or tube which forms the fibre of the cloth, so that the resulting precipitate being, as it were, imprisoned within the fibre, is rendered incapable of being removed by washing. In this way mineral colours, such as chrome-yellow, Prussian-blue, iron-buff, and manganese brown, may be applied to textile fabrics. In all these cases the proper colouring matter is insoluble in water, and is precipitated whenever the two solutions proper for its formation are mixed. Thus, when an aqueous solution of bichromate of potash is mixed with an aqueous solution of acetate of lead, an insoluble precipitate of chromate of lead (chrome-yellow) is produced. In the processes for dyeing cloth with mineral colours, the fastness of the colours is entirely a mechanical effect, in no way referable to a chemical attraction of the fibre for the colouring matter. A piece of white cotton cloth moistened with either a solution of bichromate of potash or of acetate of lead may be easily cleared of either of these salts by washing it in water; but if the cloth be first impregnated with one solution, and afterwards with the other, the precipitate of chrome-yellow produced within the fibre can never be removed by washing with water. The chrome-yellow that is afterwards washed away is merely attached loosely to the exterior of the fibre.

A second method of dyeing is with a *mordant;* a substance which is first applied to the cloth, and acts as the bond of union between it and the colouring matter. The mordant is usually a metallic salt, which has an affinity for the tissue, as well as for the colouring matter in solution; forming with the latter an insoluble compound. The name of mordant (from the Latin *mordere*, to bite,) was given by some French dyers, under the idea that it exerts a cor-

rosive action upon the fibre, expanding the pores, and allowing the colour to be absorbed. The mordants usually employed are common alum, and several salts of alumina, peroxide of iron, peroxide of tin, protoxide of tin and oxide of chrome; which have a chemical affinity for colouring matters. Many of their salts or compounds with acids have also a considerable attraction of surface for the stuffs, so that the latter have the power of withdrawing them, to a certain extent, from their solutions.

This method of dyeing is useful for all those vegetable and animal colouring matters which are soluble in water, but have not a strong affinity for tissues. The action of the mordant is to withdraw them from solution, and to form with them, upon the cloth itself, certain compounds which are insoluble in water.

In dyeing cotton with a mordant, it is generally necessary that the mordant be produced on the cloth in a form insoluble in water; but in order that it may penetrate to the interior of the cloth about to be dyed, it must first be applied in a state of solution. The excess of mordant is then removed; for, if allowed to remain, the dye would be formed chiefly on the surface, and only a small quantity would penetrate the fibre. But when the surplus mordant has been removed, and the cloth passed through the dye-beck, the resulting colour is often dull and liable to change, apparently because the quantity of mordant is too small to combine with all the colouring matter which is deposited. But on applying the same, or some other mordant, a second time, the colour is greatly improved in lustre, and becomes permanently attached. This second mordant is called an *alterant*. Thus, if a piece of white cotton be removed at once from a dilute solution of perchloride of tin to a weak decoction of logwood, the cloth assumes an uneven violet colour, which can be removed by washing. But if the perchloride be removed from the surface of the cloth before it is put into the decoction, the piece

assumes a dull, brownish, violet tint. If a small quantity of acetate of alumina be then added to the liquor, as an alterant, the cloth acquires a good violet or purple colour, which is permanent.

The method by which the superfluous mordant is removed from the surface of the cloth previous to dyeing, is by passing the dried goods through a warm mixture of cow-dung and water. This is called *dunging*. The mixture is usually contained in two stone cisterns, placed end to end, each about six feet long, three feet wide, and four feet deep. That in one cistern contains about two gallons of dung to the cistern full of water, heated to about 160° or 180°; the second cistern contains only half this proportion of dung. The dried cloth is first drawn pretty quickly through the first trough, and then immediately through the other. In passing through the cisterns the cloth is guided by rollers, to keep it free from folds. As soon as it leaves the second cistern it is washed in clear water, in what is called a *wince* pit, and again in a dash-wheel.

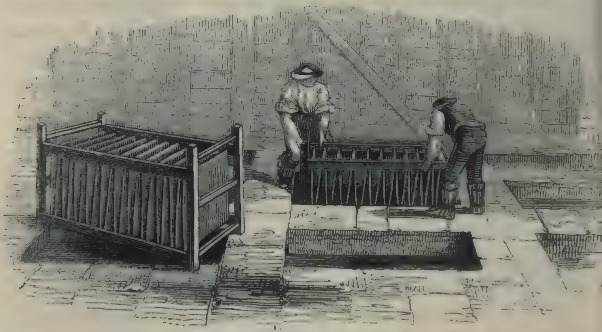
Dunging is a very important process; especially in calico printing, as will be noticed in the next treatise. Within the last few years attempts have been made to supersede the use of dung by a solution of phosphate of soda and phosphate of lime, with a little glue or some other form of gelatine. This is called *dung-substitute*, or simply *substitute*.

In a few dyeing processes, instead of dunging, the cloth is winced in a mixture of chalk and size, with hot water; the chalk serving to fix the mordant, by withdrawing the small quantity of acid remaining in it. Dunging has also been superseded, in some cases, by *branning*, that is, wincing the goods in a mixture of bran and hot water.

The mordanted goods are now ready to be exposed to the infusion of the dye stuff; and, in general, the sooner this is done, the better is the colour they assume.

A third method of dyeing is adopted when the colouring matter employed is insoluble in water. When such is the case, the mordant may be dispensed with; but it is necessary to make such a solution of the colouring substance as will allow it to be precipitated, in its insoluble state, when a cloth impregnated with the solution is exposed to some chemical agent.

The most important insoluble vegetable colours are indigo, safflower, and annatto, and some yellow and brown dyes. To bring these into a state of solution, it is necessary to employ some other solvent than pure water. By exposing indigo to the action of some body which robs it of oxygen, it is brought to the state of *white indigo*, or *indigotin*,* which is soluble in water, if lime or some other alkali be present. If a piece of cloth be dipped in such a solution, it becomes impregnated with white indigo, and on exposing the cloth to the air it imbibes oxygen, by which it becomes converted into its original insoluble blue. This remains firmly attached to the fibre, and cannot be removed by washing in water. The calico to be dyed is stretched in perpendicular folds on rectangular wooden frames. The solution of indigo is contained



DYEING IN INDIGO BLUE.

* White indigo is called *indigogen* by Liebig, who regards blue indigo as the oxide. Dumas considers white indigo not as deoxidised blue indigo, but blue indigo combined with hydrogen.

in stone cisterns or vats, the tops of which are on a level with the ground. In preparing a new vat, fifty pounds of indigo are reduced to an impalpable powder, by grinding with water, during ten or fourteen days. This powder is then mixed with hot water, and the requisite quantity of lime added, after which a solution of sulphate of iron is stirred in. Sulphate of iron consists of the protoxide of that metal dissolved in sulphuric acid: this protoxide converts the blue indigo into white indigo, which the presence of the lime enables the water to dissolve.

In the blue dye-house at the print-works of Mr. Lees, of Manchester, visited by the writer, a man and a boy have the charge of ten vats. The calico being properly stretched, the frame is lowered into a nearly spent vat, and allowed to remain 7½ minutes; it is then taken out, and left to drain for the same length of time, during which it becomes of a green colour; the frame is then turned over and immersed in the second vat, which contains a little more indigotin than the first; after remaining in this during 7½ minutes, it is taken out and exposed to the air for another 7½ minutes; it is treated in this way up to the tenth vat, which contains the largest amount of dyeing material. On being removed from this it is of a deep blue colour.

The colouring matters of annatto and safflower are scarcely soluble in water; but they dissolve readily in alkaline liquors, from which they may be precipitated by an acid. A piece of cloth being impregnated with an alkaline infusion of the dye stuff, is readily dyed by passing it through a weak acid. In practice, however, it is found desirable to add the acid to the alkaline infusion of the dye stuff, so as nearly to neutralize it; by this means the colouring matter is held in a state of feeble suspension, and readily attaches itself to the surface of the cloth.

The last method of dyeing which requires to be noticed in this place, is practised only on goods formed

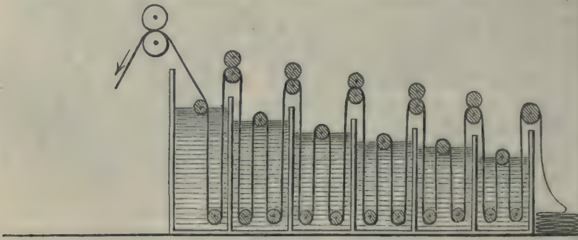
of animal tissue. By this method, which is called *mandarining,* an orange colour is given to silk and wool, not from the solution of a colouring matter, but by producing a certain change in the fibre by the action of dilute nitric acid. The orange colour is formed by the decomposition of a portion of the silk or wool by means of the acid. The yellow or orange colour which is given to quill pens is also produced by steeping them in dilute nitric acid.

FINISHING PROCESSES.

When the cloth is removed from the dye-beck, it is submitted to several finishing processes, which vary according to the method of dyeing and the nature of the stuff. It is first carefully washed in water, to separate the coloured liquid which is mechanically attached to the cloth. It is usually dried at common temperatures, but occasionally in a well ventilated apartment, heated by steam pipes. Delicate colours are always dried in the shade.

A general idea of these finishing processes may be obtained from a notice of the treatment of cotton goods, after having been dyed with a vegetable infusion, with the intervention of a mordant.

As soon as the cloth is removed from the dye-beck, it is washed in two stone cisterns of cold water, each surmounted by a reel. It is next washed at a dash-wheel; or if the action of this machine be too ener-



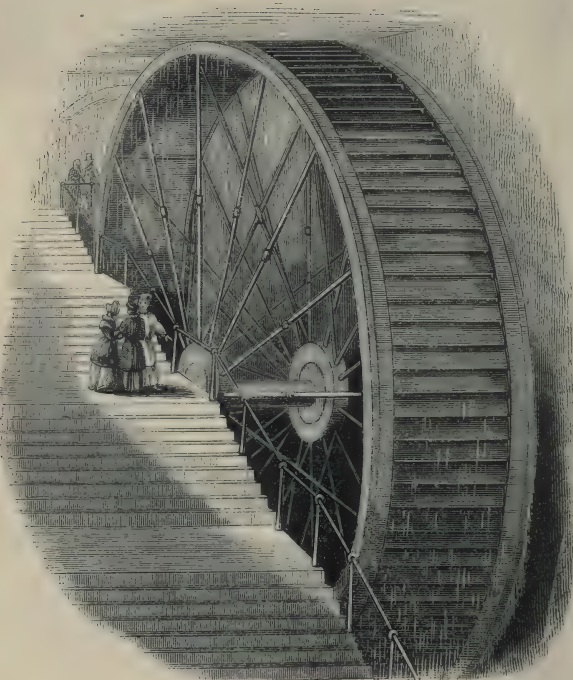
RINSING MACHINE.—*Vertical Section.*

getic, the *rinsing machine* is used. This consists of a wooden cistern, from twenty to thirty feet long, and three feet wide; it is four feet high at one end, and three feet high at the other. It is divided into a number of compartments, by partitions, which gradually decrease in height from the higher to the lower end of the vessel. In each compartment, except the highest, are three rollers, to regulate the passage of the cloth through the cistern. Above each partition are placed two more rollers, nearly in contact, and those above the higher end of the cistern and the first partition are squeezing rollers, subject to considerable pressure. The pieces of cloth to be washed are introduced into the cistern at the lower end, and pass through each compartment in succession; the motion of the squeezing rollers at the upper end drawing them through. A stream of clear water is made to flow into the cistern at the higher end, and out at the lower, while the cloth is passing in the opposite direction; by which means the cloth is brought successively into contact with cleaner portions of water, and is discharged at the top perfectly washed. The water flows from one compartment into another, through holes near the top of the partitions.

The cloth still retains an excess of colouring matter, which cannot be removed by cold water; it is therefore next rinsed in a mixture of bran and boiling water, or in soap and water. This *clearing*, as it is called, is also in some cases performed by putting the cloth for a few minutes into a solution of chloride of lime.

After the clearing, all the water is expelled by squeezing rollers, or by a rotating apparatus called the *water extracter*. The wet cloth is put into a compartment between two cylinders, and the apparatus made to perform 900 or 1000 revolutions per minute; the water is driven out by the centrifugal force through the perforations in the cylinder, whence it flows away by a gutter or drain, and in a few minutes the cloth is nearly dry.

The cloth is next folded evenly, and passed, in a length of ten pieces, through the starching mangle; then through a steam drying machine, which consists of several hollow copper cylinders, each about twenty inches in diameter and three feet in length, filled with steam. Then comes the process of calendering, which has been already described.



WATER WHEEL, AT ASHWORTH'S COTTON MILL, TURTON, NEAR BOLTON.

This wheel is 62 feet in diameter; it is of 150 horse power, and was erected at the cost of 5,000*l*.

THE

MANUFACTURE OF WOVEN GOODS.

PART III.—CALICO PRINTING.

HISTORICAL NOTICE OF CALICO PRINTING.

THE ancients seem to have been well acquainted with the art of producing a coloured pattern on cloth. Homer, who wrote about nine hundred years before the Christian era, notices the variegated linen cloths of Sidon as magnificent productions. In India the art has been practised for ages, and it derives its English name of *Calico Printing* from *Calicut*, a town in the province of Malabar, where it was formerly carried on extensively. Herodotus, who wrote more than four hundred years before the Christian era, says, that "the inhabitants of Caucasus adorned their garments with figures of animals, by means of an infusion of the leaves of a tree, and the colours thus obtained were said to be very durable." Pliny describes the art of calico printing, as practised by the ancient Egyptians. He says:—

"An extraordinary method of staining cloths is practised in Egypt. They there take white cloths, and apply to them, not colours, but certain drugs which have the power of absorbing or drinking in colour; and in the cloth, so operated on, there is not the smallest appearance of any dye. or tincture. These cloths are then put into a cauldron of some

colouring matter, scalding hot, and after having remained a time are withdrawn, all stained and painted in various colours. This is indeed a wonderful process, seeing that there is, in the said cauldron, only one kind of colouring material. Yet, from it, the cloth acquires this and that colour, and the boiling liquor itself also changes, according to the quality and nature of the dye-absorbing drugs which were at first laid on the white cloth. And these stains or colours, moreover, are so firmly fixed as to be incapable of being removed by washing. If the scalding liquor were comprised of various tinctures and colours, it would doubtless have compounded them all in one on the cloth; but here one liquor gives a variety of colours according to the drugs previously applied. The colours of the cloths thus prepared are always more firm and durable than if the cloths were not dipped into the boiling cauldron."* Mr. Parnell remarks on the above passage, that in as few words the principle of the common operations of calico printing could hardly be more accurately described.

The large cotton chintz counterpanes, called *pallampoors,* which have been made in the East Indies from a very early period, are also prepared by the application of dye-absorbing drugs; certain parts of the cloth being guarded from the action of the dye by a coating of wax. The primitive methods of India are, however, being superseded by the printing machinery of Great Britain.

When Cortez conquered Mexico, he found the inhabitants had garments with black, red, yellow, green, and blue figures. The North American Indians have also long known how to apply patterns in different colours to cloth.

During several centuries the art of calico printing was practised in Asia Minor and the Levant, but

* Pliny's Hist. Nat. lib. xxxv. cap. 11, quoted in Parnell's Applied Chemistry.

it was scarcely known in Europe till the close of the seventeenth or the beginning of the eighteenth century, when Augsburg became celebrated for its printed cottons and linens. From that city the manufacturers of Alsace and Switzerland, during a long period, obtained their colour mixers, dyers, &c. Calico printing was first introduced into England about the year 1676, by a Frenchman, who established works on the banks of the Thames near Richmond. Soon afterwards more extensive works were formed at Bromley Hall in Essex. About the year 1700, the infant art received an unexpected stimulus. In consequence of the complaints made by the silk and woollen weavers, an Act of parliament was passed, prohibiting the importation of chintzes from India; whereupon several print works were established in Surrey, to supply the London shops with these goods, which was done by printing the white Indian calicoes, the import of which was still allowed under a duty. In 1712, a duty of three-pence per square yard was imposed on this printed calico, and in 1714 the duty was raised to sixpence; but, as the importation of white calico was still considerable, the complaints of the silk and woollen weavers became louder, and they actually succeeded in inducing the legislature, in 1720, to pass an Act prohibiting the wearing of all printed calico whatever, under a penalty of *5l.* for each offence on the wearer, and of *20l.* on the seller of a piece of calico.* The operations of the printer were consequently confined to the printing of linen until the year 1730, when the law was so far modified that calico was allowed to be printed, provided the warp was of linen yarn and the weft only of cotton; and even then it was subject to a duty of sixpence per square

* Anderson's *History of Commerce.* By an Act of the same year (7 George I.), intended to encourage the silk manufacture, the wearing of buttons or button-holes made of cloth, or other stuff, was absolutely prohibited.

yard. With such obstructions the progress of the art was of course slow. In the middle of the last century only fifty thousand pieces of the mixed cloth were printed in the whole of Great Britain, whereas at the present time it is not unusual for a single manufactory to turn out, in one year, between three and four hundred thousand pieces.

About the year 1774, when the inventions made or perfected by Arkwright had introduced a new era into the history of the cotton manufacture, a law was passed, allowing printed goods made entirely of cotton to be used; subject, however, to a duty of threepence per square yard, which was raised, in 1806, to threepence halfpenny. During many years attempts were made to get this duty repealed; for, although the nominal revenue produced by it was very large, yet after deducting drawbacks on exports, and the expenses of collection, a very small sum remained. Thus, in the year 1830, a revenue of 2,280,000*l.* was levied upon 8,596,000 pieces, of which, however, about three-fourths were exported with a drawback of 1,579,000*l.* Deducting the expenses of collection, the sum of 350,000*l.* only found its way into the Exchequer. In the year 1831, the duty was wholly repealed, to the great advantage both of manufacturer and consumer. The art itself has been wonderfully improved by many of the most refined applications of chemical and mechanical science. Printed goods, which fifty years ago were sold for two shillings and threepence the yard, may now be bought for eightpence; indeed, the materials for a very pretty gown may be purchased for two shillings. This cheapness of production has so much increased the demand for printed cotton goods, that it was calculated a few years ago that not less than 230,000 persons were employed in and dependent upon the print trade for subsistence, receiving in wages the annual sum of 2,400,000*l.**

* M'Culloch's Commercial Dictionary.

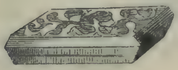
VARIOUS MODES OF CALICO PRINTING.

The union of mechanical and chemical science is most strikingly illustrated in the details of calico printing; the object of which is to apply one or more colours to particular parts of cloth, so as to represent a pattern of leaves, flowers, &c. The beauty of a *print* depends on the brilliancy and contrast of the colours, as well as on the elegance of the pattern. The process is equally applicable to linen, silk, worsted, and mixed cloths, although it is usually referred to cotton cloth, or calico.

There are various methods of printing, which will be described in the order of their simplicity, in doing which the writer has to acknowledge the kindness of Mr. Joseph Lees, jun., of Manchester, (from whose print-works much of the following information, as well as the sketches for the illustrations, were obtained;) and also Mr. Parnell's valuable work, "Applied Chemistry in Manufactures," &c.

I.—BLOCK PRINTING BY HAND.

The simplest and earliest method of imprinting figures upon calico is by means of a wooden block, upon the face of which the design is cut in relief, as in an ordinary wood-cut. The block is of sycamore, holly, or pear-tree wood, or more commonly of deal, faced with one of these woods. The block varies in size



from nine to twelve inches long, and from four to seven inches broad, and it is furnished on the back with a strong handle of box-wood. When the design is complicated, and a very distinct impression is required, the figure is sometimes formed by the insertion of narrow slips of flattened copper wire, the interstices being filled with felt.

The printing block, which is worked by hand, is charged with colour by pressing it gently upon a piece of superfine woollen cloth, called the *sieve,* stretched tightly over a wooden drum, which floats in a tub full of size or thick varnish, to give it elasticity, so that every part of the raised device may acquire a sufficient coating of colour. The sieve is kept uniformly covered with the colouring matter by a boy or girl, called the *tearer,** who takes up, with a brush, a small quantity of the colour contained in a small pot, and distributes it uniformly over the surface; for, if this were not done, the block would take up the colour unequally.

The calico is prepared for printing by *singeing, bleaching,* and *calendering.* Several pieces are then

BLOCK PRINTING.

stitched end to end, and lapped round a roller, or arranged in folds, as shown in the cut. The printing

* Probably a corruption from the French *tireur.*

shop is a long well-lighted apartment, the air of which is kept warm, for the purpose of drying the cloth as it is printed: for which purpose it is passed over hanging rollers, so as to expose a large surface to the air. The printing table, which is about six feet long, is made of some well-seasoned hard wood, such as mahogany, or of marble, or flag-stone: the object being to present a perfectly flat hard surface. This table is covered with a blanket, upon which the calico is extended, and the block, being charged with colour, is applied to its surface, a blow being given with a wooden mallet to transfer the impression fully to the cloth. It is necessary, of course, to join the different parts of the design with precision; and, in doing so, the printer is guided by small pins at the corners of the block. Thus, by repeated applications of the block to the woollen cloth and to the calico alternately, the whole length of calico is printed.

By this method, a single block prints only a single colour; so that if the design contain three or more colours, three or more blocks will be required, all of equal size, the raised parts in each corresponding with the depressed parts in all the others: in order, therefore, to print a piece of cloth twenty-eight yards long and thirty inches broad, with three blocks, each measuring nine inches by five, no less than 672 applications of each, or 2,016 applications of the three blocks, are necessary. Thus it will be seen that printing by hand is a tedious operation, requiring more diligence than skill.

When the design, however, consists of straight parallel stripes of different colours, they may be applied by one block at a single impression. For this purpose the colours are contained in as many small tin troughs as there are colours to be printed. These troughs are arranged in a line, and a small portion of each colour is transferred from them to the woollen cloth by a kind of wire brush. The colour is distributed evenly in stripes over the surface

of the sieve by a wooden roller covered with woollen cloth. For the *rainbow style*, as a peculiar pattern is called, the colours are blended into one another at their edges by a brush or rubber.

An important improvement has been made in the construction of hand blocks, by the application of a stereotype plate as the printing surface. A small mould is produced from a model of the pattern, and the stereotype copies are then made by pouring *mixed metal** into it. A number of the stereotype plates are then formed into a printing block, by being arranged in a stout piece of wood.

II.—THE PERROTINE.

On the continent, the hand-block has been superseded, to a great extent, by a machine called the *Perrotine,* after its inventor, M. Perrot, of Rouen. Dr. Ure describes it as consisting of three wooden blocks, from two and a half to three feet long, according to the breadth of the cloth, and from two to five inches broad, faced with pear-tree wood, engraved in relief, and mounted in a cast-iron frame-work. The faces of the blocks are at right angles to each other, so that each of them may, in succession, be brought to bear upon the face, back, and top of a square prism of iron, covered with cloth, and fitted to revolve upon an axis between these blocks. The calico passes between the prism and the engraved blocks, and receives successive impressions from them as it is successively drawn through by a winding cylinder. The blocks are pressed against the calico by springs, which imitate the elastic pressure of the workman's hand. Each block receives a coat of colour from a woollen surface, smeared after every

* Mixed metal consists of bismuth, lead, and tin. It is also called *fusible metal,* from the low temperature at which it melts. An alloy of two parts of bismuth, one of lead, and one of tin, fuses at 200^0, and it has the remarkable property of expanding on cooling; hence its value in stereotyping.

contact with a brush. One man, with one or two children, who act as *tearers*, can turn off about thirty pieces per day, in three colours; or as much as twenty men and twenty children could execute in block printing by hand. The Perrotine is intermediate between block printing and cylinder printing, next to be described, and is useful for some styles of work to which the cylinder machine is inadequate.

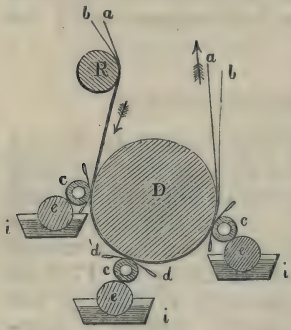
Calico has also been printed by copper plates, almost exactly the same as in printing engravings on paper, but this method has been superseded by the cylinder.

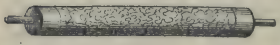
III.—CYLINDER OR ROLLER PRINTING.

The greatest mechanical improvement in this art was the invention of *cylinder* or *roller* printing, said to have been first made by one Oberkampf, a calico printer at Jouy in France. The invention was also made, independently of him, by a Scotchman named Bell, and was practised about the year 1785 at Monsey, near Preston. This style of printing has been cultivated with the greatest success in Lancashire, and is the chief cause of our superiority in this art over the continental printers, who are but little acquainted with cylinder printing. By this style, not only is the work more accurately performed than with the wooden block, but the saving of time and labour is truly remarkable. One cylinder machine, attended by one man to regulate the rollers, is capable of printing as many pieces as one hundred men and one hundred girls could print with hand blocks in the same time; or, in other words, as much work may be executed by a cylinder machine in four minutes, as by the ordinary method of block printing in six hours. A length of calico equal to one mile can be printed off with four different colours in a single hour.

The means by which these extraordinary results

are attained are sufficiently simple. The accompanying section shows the arrangement of the machine for printing a pattern upon calico in three colours: (*c*) is an engraved cylinder or roller, (also shown in a separate figure,) mounted on a strong frame-work, so as to revolve against two other cylinders (*D*) and (*e*): the cylinder (*e*) is covered with woollen cloth, and dips into a trough (*i*), containing the colouring matter properly thickened. When this roller is made to revolve, it takes up a coating of the colour, and distributes it over the engraved roller (*c*). (*D*) is a large iron drum, the surface of which is rendered elastic by several folds of woollen cloth. Round this drum travels an endless web of blanketing (*a*) (*a*), in the direction of the arrows, accompanied also by the calico (*b*) (*b*), which moves between it and the engraved cylinders. The pressure of the cylinders against each other is regulated, as occasion may require, by screws or levers.





As the cylinder (*e*) spreads the colour uniformly over the engraved cylinder (*c*), and it is wanted only in those depressed parts which form the pattern, it is obvious that the excess of colour must be removed, by some means, before the engraving comes in contact with the calico. This is accomplished by scraping the surface of the cylinder, as it revolves, with a sharp-edged knife or plate, usually of steel, called the *doctor* (*d*). This odd name has been accounted for in the following way:—When Mr. Hargreaves, a

partner in the factory of Monsey, near Preston, (already alluded to as the place where cylinder printing was first introduced,) was making some experiments with the process, one of his workmen who stood by said, "All this is very well, sir; but how will you remove the superfluous colour from the surface of the cylinder?" Mr. Hargreaves took up a common knife, which was near, and placing it horizontally against the revolving cylinder, at once showed its action in removing the colour; asking the operative, "What do you say to this?" After a moment's pause of surprise and pleasure, the man replied, "Oh, sir, you have *doctored* it!" a common phrase for "You have *cured* it;" and the contrivance has ever since retained the name of *doctor*.

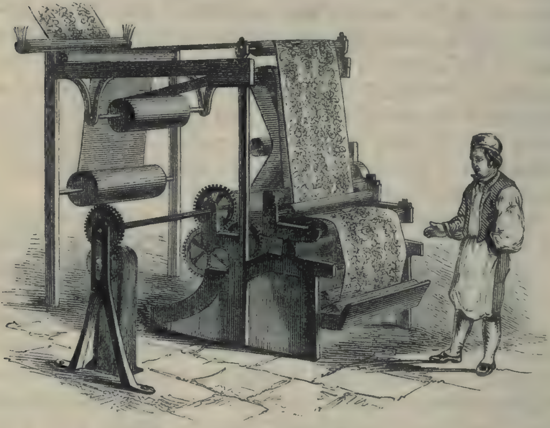
The doctor is so managed that the colour scraped off shall fall back into the trough (*i*). There are usually two doctors to each engraved cylinder; one called the *colour doctor*, and the other the *lint doctor*, (*'d*). The office of the latter is to remove the fibres which the roller acquires from the calico. Some colouring materials and mordants, such as those containing salts of copper, exert a corrosive action upon steel doctors: gun-metal, bronze, brass and iron alloys are therefore used instead of steel.

Some idea may be formed of the appearance of the cylinder machine from the sketch on the next page.

As many as eight colours may be applied at the same time, by having as many engraved rollers, each with its accompanying colour-trough, &c., revolving against the iron drum (*D*). The greatest nicety of arrangement is required to bring all these rollers to print the cloth at the precise spots required, but when once properly adjusted, each may be made to deposit its colour on the calico with certainty and regularity.

When the calico is printed, it is dried by being drawn through a long gallery or passage, which is commonly heated by the flue of a furnace which

extends the whole length of the floor of the gallery. The upper surface of the gallery is covered with rough cast iron plates, which become quickly heated, and present a good radiating surface. A piece of calico, of twenty-eight yards, is usually drawn through the gallery in about two minutes.



CYLINDER PRINTING.

The length of the printing roller may vary, according to the breadth of the calico to be printed, from thirty to forty inches; its diameter may be from four to six inches, or even a foot. Each roller is bored, and accurately turned, from a solid piece of metal. For some peculiar styles of pattern, the engraving is done by hand, but, as this is a costly operation, it is usual to adopt Mr. Perkins's method for transferring engravings from one surface to another by means of steel roller dies. The pattern is first drawn upon a scale of about three inches square, so that this size of figure being repeated a definite number of times, will cover the cylinder. This pattern is next engraved upon a roller of soft steel, about one inch in diameter,

and three inches long, so as to occupy its surface exactly. This roller, which is called the *die*, is next hardened by being brought to a red heat and then plunged into cold water. This hardened roller is then put into a rotatory press, and made to transfer its design to a similar roller, in a soft state, called the *mill*. As the design was sunk in the die, it appears in relief on the surface of the mill. This mill, being hardened, is put into a rotatory press, and is made to engrave or indent upon the large copper cylinder the whole of the intended pattern. By this process, the cost of an engraved cylinder may not be more than about 7*l*., but if engraved by hand it would cost upwards of 50*l*. By the same method, a worn-out cylinder can be easily restored, by rolling the mill over the copper surface.

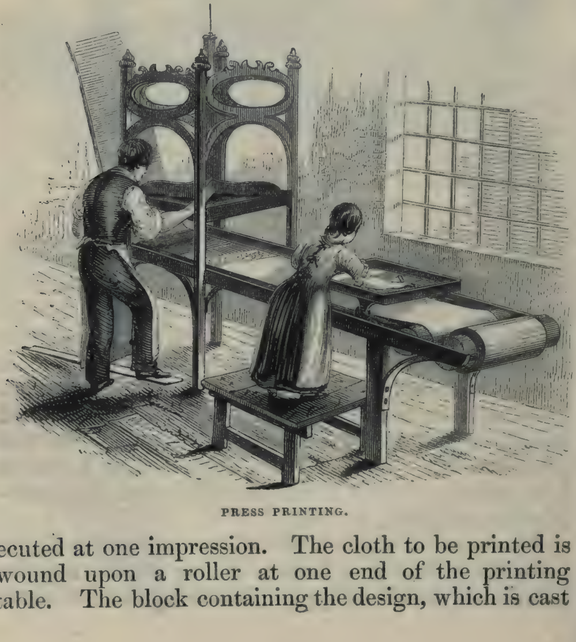
The pattern is also sometimes produced on the cylinder by *etching*. The cylinder is covered with a thin coat of varnish, and on this the pattern is drawn, with a diamond-pointed tracer. The cylinder is then immersed in dilute nitric acid, which corrodes or engraves all the parts from which the varnish has been removed by the tracer. The tracer is generally applied by a process similar to the eccentric chuck of a lathe, and thus the entire surface is covered with patterns, or ground-works of patterns, of infinite varieties of form, and some exceedingly beautiful. Cylinders, eccentrically engraved, are largely exported from Manchester, both to the Continent and to North America; and the foreign printer adds the pattern, either by hand or with the steel cylinder. The Germans send their own designs to be engraved on the cylinders, having previously selected the ground-work. The value of a copper roller, before it is engraved, is about 5*l*. or 7*l*.: the value of engraving varies from 5*l*. to 10*l*.

There are other methods of producing the design upon the printing cylinder, among which may be mentioned the electrotype. The design is also some-

times cut in relief upon wooden rollers: or formed by the insertion, edgeways, of flat pieces of copper wire. This is *surface printing*, which Dr. Ure thinks was probably so called because the thickened colour is applied to a tense *surface* of woollen cloth, from which the roller takes it up by revolving in contact with the cloth. When these wooden rollers are combined with copper ones, the machine is called the *union* printing machine.

IV.—PRESS PRINTING.

The last method of calico printing is *press printing*, which is a refined improvement on block printing. By this style, several different colours can be ex-



PRESS PRINTING.

ecuted at one impression. The cloth to be printed is wound upon a roller at one end of the printing table. The block containing the design, which is cast

in mixed metal, is about $2\frac{1}{2}$ feet square, and is supported, with its face downwards, in an iron frame, so as to be raised or lowered at pleasure. The face of the block is divided into as many stripes, crossways with the table, as there are colours to be printed. Now, supposing the pattern to be made up of five stripes, of different colours, each stripe six inches in breadth, and as long as the breadth of the cloth, the question is, how are the colours to be applied without mingling and disturbing each other?

Near one end of the table is a shallow tray or frame, resting upon wheels, so as to be easily moved backwards and forwards along a railway. This frame contains a cushion, of about the same size as the face of the printing block, and by the side of the cushion are, arranged in a line, five little troughs, containing the thickened colours. By means of a long piece of wood, so formed as to dip into all the troughs at once, the tearer applies a small quantity of each of the five colours to the surface of the cushion, and then spreads them evenly into five stripes, by means of a brush, without any intermixture. The breadth of these stripes is the same as the breadth of the stereotype rows on the block.

The cushion being thus charged, the frame is moved along the railway until it comes immediately below the printing block, which is then lowered by the pressman upon the cushion, by which means each of the five stripes on the block is charged with its proper colour. The block is then raised, the colour frame withdrawn, and the block allowed to descend upon the cloth, which it imprints with five rows of different colours. When the block is raised, the cloth is drawn forward, in the direction of its length, about six inches, or exactly the width of one stripe on the block: the tearer again pushes forward the cushion with more colour, and the block is again charged and applied to the cloth. As a length of the cloth equal to the width of a stripe is drawn from

underneath the block at each impression, every part of the cloth is brought into contact with all the stripes on the block. The action of this machine is very beautiful; but the utmost nicety is required in adjusting all the moving parts of the press, to prevent the colours from mingling and distorting the pattern.

VARIOUS STYLES OF CALICO PRINTING.

Although the different methods of printing are almost as numerous as the different kinds of pattern, yet each colour in a pattern is always applied by one of six different *styles* of work; by the proper combination of two or more of which, the cloth may be ornamented with any pattern, however complicated. The styles are quite distinct from each other in the processes adopted for obtaining the desired result.

I.—THE MADDER STYLE.

The first is called the *madder style*, from the circumstance of its being chiefly practised with *madder*; but it is also applicable to most soluble vegetable and animal colouring matters.

In giving a short sketch of the processes required in printing in the madder style, it will be necessary to state a few particulars which apply more or less to every style. For example, the mordant or colouring matter must be properly thickened to prevent it from extending beyond the proper limits of the design. The choice of proper *thickeners* requires great experience and attention. Two similar solutions of the same mordant equally thickened, but with different materials, give different shades of colour when dyed in the same infusion. The most useful thickener is wheat-starch and flour; but many others are used, such as gum arabic, British gum, high-dried potato-starch, gum senegal, gum tragacanth, jalap, pipe-clay or China-clay mixed with gum, dextrin, potato and

rice-starch, sulphate of lead mixed with gum, and many others.

When the cloth is printed with the mordant, and passed through the hot flue, it is frequently conducted to what is called the *ageing room*, where it is suspended free from folds for one or two days. The air of this room is kept as much as possible in its natural state; and the object of this suspension is, that the greater part of the mordant may undergo a chemical alteration, by which it becomes attached to the cloth in an insoluble state.

The next process is *dunging*, which has been already described in the treatise of dying. It is one of the most important steps in calico printing, where the mordant is printed so as to produce a pattern; for if all the mordant which remains in a soluble form is not completely removed, a portion of it may become distributed over the whole surface of the cloth when the pieces are washed in water or put into the dye-beck. Dunging, therefore, not only removes the superfluous mordant, and the thickening paste by which the mordant is applied, but determines a more intimate union between the mordant and the stuff. This process is necessary for all kinds of alum, iron and tin mordants, when applied to the cloth before the colouring matter.

After the dunging, the cloth is washed in cold water, and winced in a weak solution of substitute* and size. It is then ready for the dyeing liquid, in which it is constantly turned by a wince for two or three hours. On those portions of the cloth on which the mordant has been applied, the colouring matter attaches itself in a durable manner; but on the unmordanted portions the colour is feebly attached, so that it may be wholly removed by washing, either in soap and water, in bran and water, or in a dilute solution of chloride of lime. This last washing is called *clearing*.

* This term is explained in Dyeing, p. 431.

The above is a mere outline of the most important processes required for printing and dyeing a piece of calico according to the madder style. It gives no idea of the number of operations actually required for finishing a piece of cloth. In order to produce so simple a pattern as a red stripe upon a white ground, the bleached cloth has to go through no less than nineteen operations.

1. Printing on mordant of red liquor,* thickened with flour, and drying.
2. Ageing for three days.
3. Dunging.
4. Wincing in cold water.
5. Washing at the dash-wheel.
6. Wincing in a solution of dung substitute and size.
7. Wincing in cold water.
8. Dyeing in the madder-beck.
9. Wincing in cold water.
10. Washing at the dash-wheel.
11. Wincing in soap-water, to which a salt of tin has been added.
12. Washing at dash-wheel.
13. Wincing a second time in soap-water.
14. Wincing in solution of bleaching-powder.
15. Washing at the dash-wheel.
16. Drying by the water-extractor.†
17. Folding.
18. Starching.
19. Passing through the steam drying machine.

II.—PRINTING BY STEAM.

The second style of calico printing is *printing by steam*, and is regarded as one of the most important modern improvements in the art. There are not many colours which attach themselves firmly to the

* Red liquor is a preparation of alumina.

† This machine has been explained in the treatise on Dyeing, p. 435.

cloth by being merely printed on it with the mordant, but by exposing the printed goods for a short time to the action of steam, an intimate combination takes place between the tissue, the colouring matter, and the mordant.

There are different methods of steaming. In some the goods are introduced into a large stout deal box, the lid of which is made nearly steam-tight by edges of felt. The steam is admitted near the bottom by a thickly-perforated pipe, which traverses the box. At some print-works the steam is admitted into a small chamber of masonry, about four or five feet in length, by three in width, and three feet high. The cloth is suspended free from folds on strings across the chamber.

But the most common method is that adopted at Mr. Lees's print-works, as shown in the accompanying sketch. Three or four pieces of the printed and

STEAMING.

dried calico are stitched together at the ends, and coiled round a hollow cylinder of copper, about three feet long and four inches diameter, perforated with holes half an inch distance from each other. One end of the cylinder is connected with a steam-pipe, the other end being closed. The calico is prevented from coming immediately in contact with the cylinder by a roll of blanket stuff, and is covered with a piece of white calico tightly tied round the roll. During the lapping of the calico the cylinder is placed horizontally in a frame, in which it is made to revolve, but during the steaming it is fixed upright within a small apartment, furnished with a chimney to carry off the steam. The steam is supplied from the main steam-boiler of the works, the quantity being regulated by a stop-cock. Its temperature is kept at 211° or 212°, to prevent much condensation, which causes the colours to run. A higher temperature is found injurious, but a slight condensation is required to keep the goods moist. The steaming is continued from twenty minutes to three quarters of an hour, according to the nature of the stuff and the colouring mixture. When the steam is cut off, the cloth is immediately unrolled, to prevent condensation; it is then in a soft and flaccid state, but on exposure to the air for a few seconds the substance employed as a thickener solidifies, and the goods become dry and stiff. The cloth is next aged for a day or two, and then the thickener is separated by gently washing in cold water.

There are some colouring matters which, on being applied to the cloth in a state of solution, become firmly attached to it without a mordant and without steaming, but merely by exposure to the air. A vast variety of cheap goods are also printed for some of the foreign markets in *fugitive* colours, which, not being fixed by steaming, are called *spirit*, *fancy*, or *wash-off* colours. The process of steaming is, however, desirable in most of the examples of this style;

for by its means not only is the colour as firmly attached as in any other style, but it presents a brilliancy and delicacy of finish hardly attainable by any other process.

III.—THE PADDING STYLE.

The third style of printing is called the *padding style*, and is applicable to mineral colours. By this style, not only may a pattern be produced on white or coloured ground, but a ground may also be formed for the reception of the design in other colours.

In order to imbue the cloth uniformly with a liquid, the *padding machine* is used. This is almost the same as the starching mangle, described in the treatise on calendering, the trough containing the thickened colouring matter instead of starch. A roller covered with blanket stuff dips partly into the trough, and above this is another cylinder, the cloth to be padded passing between the two. The cloth is then dried at a temperature of 212°. If the colour is to be applied to the face of the cloth only, the common printing machine with a roughened roller is used instead of the padding machine.

In order to impart to the entire surface of the cloth the colour desired, the cloth is impregnated successively with the two solutions necessary to produce the effect; or else the cloth is padded in one of the solutions, and afterwards winced in the other. To produce a design in a mineral colouring matter, on a white or coloured ground, the cloth is usually first printed with one of the solutions, and then either padded or winced in the other.

IV.—THE RESIST STYLE.

The fourth style of printing is called the *resist style*. The white cloth is first imprinted with a substance called *resist paste*, or simply the *resist*. Its office is to prevent those portions of the cloth on

which it is applied from acquiring colour when the cloth is afterwards passed through the dye-beck. The simplest effect of this style is the production of a white design on a coloured ground. There are two classes of resists, one is applied to prevent the attachment of a mordant, and the other that of a colouring matter. Some resists, such as those called *fat resists*, act mechanically; others act both mechanically and chemically.

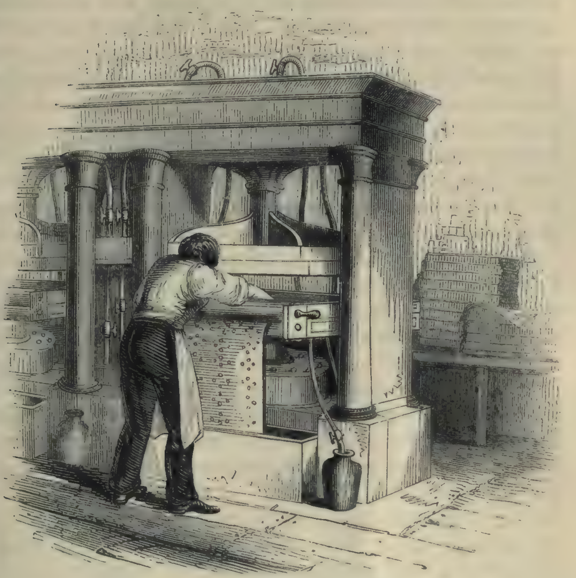
V.—THE DISCHARGE STYLE.

The fifth style is called the *discharge style.* The object is to produce a white or coloured figure upon a coloured ground. This is effected by printing a pattern upon the already dyed or mordanted cloth, with a substance called the *discharger*, which, like the resist paste, acts either on the colouring matter, or on the mordant before the cloth is exposed to a dyeing liquor. The essential property of a discharger is to convert the substances on the cloth into colourless or soluble products, which may be removed from the cloth so as not to interfere with the subsequent application of a colouring material to the parts discharged. Chlorine and chromic acid are usually employed for discharging a vegetable or animal colouring matter; and an acid solution for dissolving a mordant.

One of the most interesting examples of this style is the imitation of Bandana handkerchiefs, in which white figures are produced on a ground of Turkey-red, by means of an aqueous solution of chlorine. This is made to flow down through the red cloth in certain points, which are defined and circumscribed by the pressure of hollow lead types, in plates, in a hydraulic press.

In the Bandana gallery of Messrs. Monteith at Glasgow (as described by Dr. Ure, whose account we abridge), sixteen presses similar to the one shown in the figure are arranged in a line. All these presses

are worked by two press cylinders of peculiar construction, having solid rams accurately fitted to them. To each of these cylinders are connected three little



BANDANA HANDKERCHIEF-PRESS.

force pumps, worked by a steam-engine. Each press is furnished with a pair of pattern plates, one fixed to the upper block of the press, and the other on the moveable part, or *sill*. From twelve to fourteen pieces of cloth, previously dyed Turkey-red, are stretched over each other as evenly as possible, and then rolled round a drum, which is placed at the back of the press. A portion of the fourteen layers of cloth, equal to the area of the plates, is next drawn through between them by hooks attached to the two

corners. On opening a valve connected with one of the driving cylinders, the water enters the cylinder of the press, and instantly lifts its lower block, so as to apply the under-plate with its cloth close to the upper one. This valve is then shut, and another is opened: the pressure of five tons in a one-inch cylinder is now brought to bear on the piston of the press, which is eight inches in diameter. The effective force will therefore be 5 tons $\times$ 8^2, or the square of 8, or 64 $=$ 320 tons; the areas of cylinders being to each other as the square of their respective diameters. The cloth is thus condensed between the leaden pattern plates with a pressure of 320 tons in a couple of seconds.

The next step is to admit the chlorine or discharging liquor to the cloth. This liquor is contained in a small leaden cistern attached to each press, and the quantity admitted to the cloth is regulated according to the pattern of discharge. On turning a glass stopcock it flows into the hollows in the upper lead plate, whence it descends on the cloth, and percolates through it, extracting in its passage the Turkey-red dye, the intense pressure preventing the liquid from spreading beyond the limits of the figure perforated in the lead plates. The liquor is finally conveyed into a waste-pipe, from a groove in the under-block. As soon as the chlorine liquor has passed through, water is admitted in a similar way to wash away the chlorine; otherwise upon relaxing the pressure, the outline of the figure discharged would become ragged. The passage of the discharged liquor, as well as of the water, through the cloth, is occasionally aided by a stream of compressed air, made to act in the direction of the liquid upon the folds of the cloth. When the demand for goods is very brisk, the air apparatus is much employed, as it enables the workman to double his product.

One workman superintends four presses. The time requisite for completing the discharging process in

the first press, is sufficient to enable the other three workmen to put the remaining fifteen presses in play. The discharger proceeds now from press to press, admits the liquor, the air, and the water; and is followed at a proper interval by the assistants, who relax the pressure, move forwards another square of the cloth, and then restore the pressure. Whenever the sixteenth press has been liquored, &c. it is time to open the first press. In this routine, about ten minutes are employed; that is, 224 handkerchiefs (16×14) are discharged every ten minutes. The whole cloth is drawn successively forward to be successively treated in the above method. When the cloth escapes from the press, it is passed between the two rollers in front; from which it falls into a trough of water placed below. It is finally carried off to the washing and bleaching department, where the lustre of both the white and the red is considerably brightened.

By the above arrangement of presses 1600 pieces, consisting of 12 yards each = 19,200 yards, are converted into Bandanas in the space of ten hours by the labour of four workmen.

VI.—THE CHINA-BLUE STYLE.

The last style of printing is for *China blue*, a peculiar style practised with indigo only, two or three different depths of colour being commonly associated with white. The bleached calico is printed in the pattern required, with a mixture of indigo, orpiment, sulphate of iron, gum and water. It is then suspended for a day or two in a dry atmosphere, and stretched in perpendicular folds on a rectangular wooden frame, and dipped in a certain order in the three following liquids, contained in stone cisterns, the tops of which are on a level with the ground:* 1. Milk of lime;

* A representation of these troughs is given in the treatise on Dyeing, p. 432.

2. Solution of sulphate of iron; 3. Solution of caustic soda. The frames are dipped several times alternately in the first and second cisterns, with exposure to the air for a short time between each dip: they are not dipped so frequently in the third trough,—but the dipping in this immediately follows No. 2. By these operations the insoluble indigo blue which has been applied to the surface becomes converted into indigotin, which is dissolved, and transferred to the interior of the fibres, where it is precipitated in the original insoluble form.

PATTERN DESIGNERS.

The beautiful combination of mechanical and chemical principles upon which the calico printer depends for the success of his art, would nevertheless avail him but little were he to neglect the public craving after novelty. Every year the "spring fashions" must all be new, so that there is a constant demand for new designs to gratify the public taste. The large printers usually have a set of designers, consisting of two or three men and four or five apprentices, attached to their establishments, for supplying a large number of designs, often amounting to several thousand a year, from which the printer selects those which he thinks likely to prove successful, either from the elegant distribution of form and colour, or novelty of design. The making of designs is also a separate trade of itself in Manchester, the designers finding a ready sale for their inventions among the printers. Some designs are purchased for a few shillings, and others procure as high a price as twenty pounds. A skilful designer may meet with permanent employment at five or six guineas a week; but the average wages of a designer varies from thirty-five to fifty shillings a week.

An act of parliament passed in the thirty-fourth year of the reign of George III., enacted that the inventor or printer of any new and original pattern for printing linen, cotton, calico, or muslin, shall have the sole right of printing and reprinting the same for three months, to commence from the day of first publication. It was long felt, however, that this term was not a sufficient protection. Printers would not get designs from eminent artists, which, after three months, would become public property, and hence they allowed the continental printers, especially the French, to excel us in the novelty and elegance of their designs, as much, or perhaps more, than we exceeded them in the mechanical departments.

At length a parliamentary inquiry was instituted, with a view to extending the Copyright of Designs; and in the year 1840, a Select Committee of the House of Commons published their report, which was favourable to such extension. In September 1842, a new Act came into operation, by which a copyright of nine months was secured to designs for "garment printing," while those for "furniture printing" obtained a copyright of three years, every design being registered in a book kept by a registrar appointed by the Board of Trade. It will be supposed, from the greater protection awarded to furniture prints, that they are of a more costly description than garment prints. Such is the case, the mere drawing and engraving of some of them costing from fifty to a hundred pounds. A still greater expense is incurred in "making out the pattern;" that is, reducing it to such a scale, and making such a distribution of its parts, as will make the several portions "justify" or harmonize with each other when engraved on separate blocks or cylinders. Some patterns require to be drawn five or six times, because the least imperfection in furniture designs is at once detected.

From the Minutes of the Evidence taken before this Committee, much information may be obtained respecting the production of designs. Mr. Salis Schwabe, a calico printer at Manchester, stated that his designing establishment cost about 800*l.* a year. In the year 1838 between two and three thousand designs were produced, of which number 500 were selected and engraved. The whole cost for designing and engraving these patterns amounted to between 5,000*l.* and 5,500*l.*, or an average cost of 11*l.* per pattern, about 700 rollers being required to make out the 500 patterns. Of these patterns 100 were decidedly successful, and 50 had a middling result. The cost of the unsuccessful patterns must of course be borne by the successful ones, in which case the cost of each successful pattern would be about 35*l.*

At Mr. Schwabe's establishment two or three months are generally occupied in designing and engraving patterns previous to their being ready for taking orders. Designs for light goods are got ready for the engraver in June, and the two following months. In August the engravers have completed a portion of their work, and in September the first exhibition of patterns takes place, preparatory to sales for the distant markets, such as those of South America; but many of these patterns are suitable for the home market afterwards. Orders are taken for the home market in January, and the goods are delivered in February and March; so that the same designs may be published for one market in October, and for the home market in March. The sale continues throughout the summer.

In employing designers upon any particular work, the master describes the style of the pattern, the stripe, check, diagonal set, natural flowers, or other objects. Another pattern is never exhibited, for as Mr. Schuster says, "I have found by experience that indolence is an inherent quality even of drawers,

and that they will come very near if I give them a pattern, and consequently I have desisted from that plan." The same witness states, that a pattern "assists the drawer in remaining idle, in not exerting his own ingenuity in composing, and he thinks it is against producing *novelty*," which is the thing most wanted.

One of the most novel and original patterns ever produced was by an accident, which occurred at the house of Messrs. Simpson & Co., of Fox-hill Bank. Having to print a quantity of cloth in parallel stripes, as one piece was going up on the blanket,* the next piece came in another shape on the other side, and cut a little across the pattern, so that the stripes being thrown angularly on each other, produced a new effect, which received the name of the *Diorama pattern*. This was for a time so great a favourite, that the printers are said to have sold 25,000 pieces of it in one day.

When a pattern is approved, it is examined to see that every *repeat* is equidistant, that it is repeated at proper distances, and that there are not four sketches and a half, or five and a half, or five and a quarter, in what would be the circumference of the roller, and to prepare a sketch, so that it may exactly agree with the roller.

A very general opinion was offered before this committee, that the art of design had retrograded, rather than advanced, in England. When the printing trade was confined to the vicinity of London, pattern-drawing flourished. Mr. Thomson, of Clitheroe, says, "The designs of several distinguished artists are still remembered with admiration; and Raymond, Kilburn, Wagner, and Edwards, are regarded as the old masters of the English school of design in calico-printing. I have the good fortune

* See the diagram at p. 448.

to possess a volume of drawings of this period, in which pattern-drawing is elevated to the dignity of a fine art. The art of printing, since that period, has made gigantic strides, and is now one of the most beautiful and refined of the chemical arts. The art of designing has at the same time retrograded." Other witnesses stated, that the best printers did not hesitate to copy French patterns almost exactly. Much, however, has been done since the date of this inquiry, and is doing, to educate and improve the taste of English pattern-drawers, by the establishment of schools of design, and greater encouragement which printers can afford to give under the extended copyright.

As the designers are constantly engaged in the production of new patterns, and produce them by thousands a-year, it would seem, at first view, almost impossible to produce novelty. Such, however, is by no means the case. Mr. J. Lockett says, "You may give a rose to a thousand different persons. I may say we have engraved the rose pattern and the rose-bud a thousand times; and I will produce a thousand patterns with the rose-bud engraved, and I will defy any man to say that there is the least identity in them."

The fullest information, however, on the subject of novelty of design is obtained from the evidence of Mr. T. B. Holdway, a pattern designer and teacher of pattern drawing.

2743.—"Will you state to the committee what you consider to be an original design?—I have studied something upon that point. All design is derived from the line and the circle, or a part of the circle; the objects which compose patterns are obtained from those combinations. A pattern is the grouping of those objects. Now, it is very true that I may not get a very great number of new objects, but by paying attention to the harmony and grouping of the line

and circle together, I may create very different objects. There are a great number of objects used in the various kinds of patterns, and those objects being judiciously thrown together compose a new pattern.

2748.—" What constitutes an original?—This I illustrate by a simile. I consider that in music we have a certain number of notes, and a composer in music has to use every one of those notes, and, by transposing those notes, he creates a great variety of airs, and they are said to be his composition. I say that I have less materials than he has; I have but a part of a circle and the line; upon those all designs are founded, and I must group and transpose those objects that I create from these materials into the most harmonious and pleasing effects, so as to create a good design.

2759. " In producing designs, do you not consult a variety of designs already existing in silk and cotton, and on paper, the productions of this and of foreign countries, in the formation of your patterns?—I have done so, in the same way as I would read a good book to get ideas.

2760. " Have you not, in point of fact, formed your patterns entirely from designs which were placed before you?—No. I think that I have made a good many original designs; but it must be from grouping those objects which compose good patterns, in the various modes that form the style. We do not use the rose and thistle, and all natural flowers, in the shawl: we use an incongruous lot of objects, that are only adapted for that style.

2761. " Is it not your constant custom to take ideas, in the formation of your designs, from other designs?—It is not my custom.

2762. " You have stated, that you consult other designs?—Yes. I consider that a person ought to have a good collection of designs, that he may vary his own; it is by seeing designs that he is enabled to

do so: but I consider a person only copies a design when he takes it as it stands.

2769. "The point I wish to elicit is this, whether or no you consider a pattern an original design of your own, which is entirely composed of objects that you have taken from other patterns, but differently arranged in that from what they are upon the original pattern?—I should say, that all patterns consist of objects that may have been seen before; therefore I hold, that a party taking a very great portion of the objects in any article, should be considered a copyist; but that would be a question for practical men to decide, and which, as I stated before, no court of law could determine; it must be referred to practical men, and those practical men must be acquainted with the business of printing for calicoes, for carpets, or shawls, or any other manufactures.

2770. "Do you consider, that, in the vast quantity of patterns which have been designed during the fifty years the law has been in existence, which may be calculated as many millions, every object which you can find in patterns, or that your imagination can furnish you, has not appeared in some of those patterns?—It may be so; but I consider that the invention of designs must be rather on the increase than the decline, in consequence of the number that have been invented; and that there is as much scope as ever in the branches of fancy trade, for every manufacturer to invent for himself; it is *ad infinitum*, the inventing of patterns.

2771. "If ideas have been ranged together in those countless millions of patterns, does it not appear to you that it is impossible to introduce new ideas? —I think it is possible to introduce new ideas.

2778. "Does it not strike you, that it is a difficulty almost amounting to impossibility to invent an original design?—I do not think it is; because, if you could enclose me in any place with working materials, but without any pattern to copy from

whatever, I could produce a new design, different from any thing yet produced, and I could find others to do the same."

STATISTICS OF THE COTTON TRADE.*

Mr. Huskisson stated in the House of Commons, in March, 1824, that he believed the total value of the cotton goods then annually manufactured in Great Britain amounted to the prodigious sum of *thirty-three and a half* millions; and Mr. M'Culloch, writing in 1833, says, "We believe we shall be about the mark, if we estimate their present value at *thirty-four* millions!" which sum he distributes in the following manner:—

	£
Raw material, 240,000,000 lbs. at 7*d.* per lb.	7,000,000
Wages of 800,000 spinners, weavers, bleachers, &c., at 22*l.* 10*s.* a-year each	18,000,000
Wages of 100,000 engineers, machine-makers, smiths, masons, joiners, &c., at 30*l.* a-year each	3,000,000
Profits of the manufacturers, wages of superintendence, sums to purchase the materials of machinery, flour, coals, &c.	6,000,000
	£34,000,000

The capital employed may be estimated as follows:—

	£
Capital employed in the purchase of the raw material	4,000,000
Capital employed in payment of wages	10,000,000
Capital vested in spinning-mills, power and hand-looms, workshops, warehouses, stocks on hand, &c.	20,000,000
	£34,000,000

* For further particulars the reader is referred to the two Treatises on the Manufacture of Cotton Yarn.

Statement of the Quantity and declared Value of British Cotton manufactured Goods exported from the United Kingdom:—

	1820.	1830.	1840.	1842.	
White or plain cottons	113,682,48	244,799,032	433,114,373	435,519,311	yds.
Printed or dyed cottons	134,688,144	199,799,466	357,517,624	298,579,498	yds.
Hosieryand small wares	£496,580	£1,175,153	£1,265,090	£1,020,664	value.
Twist and yarn	23,032,784	64,645,342	118,470,223	137,466,892	lbs.
Total declared value	£16,516,748	£19,428,664	£24,668,618	£21,679,348	

In the three years following 1842, the total quantities and declared value of cotton manufactures (exclusive of hosiery, lace, small wares, twist and yarn), entered by the yard, were as follows:—

	Yards.	Value.
1843.	918,640,205	£15,168,464.
1844.	1,046,670,823	17,612,146.
1845.	1,091,686,069	18,029,808.

In 1844, the total declared value of exported British cotton manufactured goods amounted to £25,805,348.

By a recent Parliamentary document, it appears that the following exports of cotton goods were made in the year ending June 16, 1846:—

Plain Cottons	663,771,123	yards.
Printed and Dyed Cottons	327,465,580	"
Cotton Yarns	146,243,690	lbs.
Cotton Thread	2,960,798	"

FULLING STOCKS.

THE

MANUFACTURE OF WOVEN GOODS.

PART IV.

THE MANUFACTURE OF WOOLLEN CLOTH.

THE processes by which wool is converted into woollen and worsted yarns have been detailed in a former treatise. Worsted stuffs, whether plain or twilled, are, for the most part, complete and fit for the market as soon as they are woven; but when woollen cloth is taken from the loom, it requires a number of curious and elaborate finishing processes, which must now be described.*

There is nothing that calls for particular remark in the weaving† of woollen yarn, except the large size of the looms, which allow of broad cloth, upwards of twelve quarters wide, being woven. This great width is necessary to allow for the shrinking which it undergoes in scouring and fulling. A cloth required to be sixty inches wide when finished, must be woven of the width of about one hundred inches.

* The writer has again to acknowledge the liberal assistance to himself and the artist, furnished by Messrs. John Brooke and Sons, of Armitage Bridge, near Huddersfield.

† For the details of weaving the reader is referred to a previous Treatise on the Manufacture of Woven Goods.

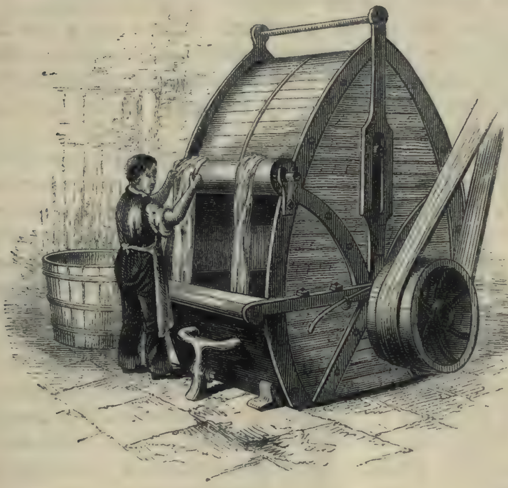
The cloth is furnished at the loom with outer edges of list for receiving the tentering hooks when it is stretched out to dry. In the West of England this list is made of goat's hair, and in Yorkshire of coarse yarn. In this, as in every other description of weaving, the power loom is rapidly superseding the hand loom.

SCOURING.

In the preparation of the wool for spinning, a quantity of oil is employed, which, together with the size used for the dressing, is left in the cloth when the piece is received from the loom. In this state it is greasy and rough, and the object of the processes about to be described, is to give it a smooth and level surface. The oil and size must first be got rid of, for which purpose the cloth is scoured at the *fulling mill*, which is a somewhat rude machine—supposed to stand, in point of antiquity, next after the corn or flour mill. Scouring consists in constantly agitating and exposing new surfaces of the cloth to the action of water containing some detergent substance. During many centuries a kind of clay, called *Fullers' earth*, was used for the purpose. It is found in great abundance in several parts of England, especially in Bedfordshire, Berkshire, Hampshire, and Surrey. Its value depends upon the affinity which the alumina contained in it has for greasy substances; but it is much less used than formerly, and only preparatory to scouring with soap.

The fulling-mill consists of two or more ponderous oaken mallets, working in a *stock*, as the frame of the mill is called. The mallets are worked by *tapit* wheels, the rims of which are furnished with projections, which, bearing upon the shanks of the mallets, raise them to a certain height, and then, suddenly releasing them, allow the heavy heads to fall by their own weight. The cloth is exposed to

the action of the mallets in an inclined trough, the end of which is curved, so that the cloth is turned round and round by the action of the stocks, and every part by turns exposed to them. When sufficiently beaten, a stream of hot water is allowed to flow through the trough until the cloth is perfectly clean, or the cloth is taken to a scouring machine, and



SCOURING MACHINE.

washed in hot water with the assistance of squeezing rollers.

FULLING.

After the cloth has been scoured, the naked threads are very perceptible; it is then placed in the fulling-mill, and fulled for many hours, the object being to produce such a motion among the fibres of the wool, that their minutely jagged surfaces may lock into each other, and form not a woven tissue like calico or linen, but a *felted* mass similar to paper.

In a piece of thick fulled cloth the separate threads are almost lost under the thick fulled surface which is raised upon them: and the chief object of spinning and weaving seems to be to distribute the fibres equally, and to give strength to the fabric, rather than any particular character of woven goods. Indeed, during the last half century, several attempts have been made to produce cloth by fulling only, without the aid of weaving. There are a few factories now in operation which produce an excellent felted cloth fit for carpets, and the production of superfine broad cloth by the same means does not appear impossible.

The fulling stocks resemble the scouring stocks, but the trough has a square instead of an inclined end, so that the cloth receives the direct stroke of the mallets, and is not turned round and round as in scouring. A large number of these stocks are contained in one long room upon the ground-floor, and the continual thumping which is going on from the ponderous mallets has a very odd effect. It seems astonishing how the cloth can escape being pounded to dust, or at least worn into fragments; but the cloth is not injured on account of the number of the folds, and the directness of the blow, which falls with much greater force than in the scouring stocks.

The old fulling mill was constructed of wood, but it is now usually of iron, and all the parts are fitted and adjusted with great care. The trough is sometimes made hollow, so as to form a steam-chest connected by a pipe with the boiler, for maintaining the degree of heat most favourable to the felting process. There is also a contrivance for altering the form of the trough so as to vary the force with which the mallets fall upon the cloth, different qualities often requiring different degrees of force. This is accomplished by a moveable curved plate, traversing on a fixed hinge-rod at the bottom of the trough: the upper end of

this curved plate admits of being advanced towards or withdrawn from the mallets, by means of a screw rod attached to its back.

Soap is employed in this process, about six pounds being required for a piece of coloured cloth containing from forty to fifty yards. White cloth fulls more easily than coloured, and in less time; and it requires less soap. The soap is first converted into shavings for the purpose of easier solution, and then one-half of it is dissolved in two buckets full of hot water. A portion of this is distributed over the cloth by pouring it in a fold near one of the ends; the man then takes up this fold and pulls out the cloth so as to form a sort of channel, along which the solution of soap flows, until the cloth has absorbed it all; he then adds another quantity, and pulls out the cloth as before.* The cloth is next put into the trough of the mill, and fulled for three hours. It is then taken out and stretched; and immediately returned to the trough without any fresh soap, and fulled for two hours longer. It is again taken out and the second half of the soap is distributed at four different times over the cloth, taking it out every two hours to be stretched, and to get rid of wrinkles. At the end of twelve hours a stream of clean water is admitted to wash away the soap, or the cloth is again passed through the scouring machine. The piece is then taken out, and dried. The effect of fulling is to reduce the piece in breadth about two-fifths, and in length one-third.

TENTERING.

The old method of drying, which is sometimes still adopted, is to stretch the cloth, by means of tenter-hooks, upon a long frame of wood, in an open

* See Frontispiece.

field, called the *tenter-ground.* The drying is now usually carried on more expeditiously in a room heated by steam pipes, the tenter-frame being used as in the open air. In stretching the piece on the tenter-frame it is drawn out about two yards in forty, but very little in breadth.

BURLING.

The operation of burling sometimes takes place immediately after scouring or fulling. A number of young women, called *burlers,* carefully examine the cloth on the surface, and through the web, against a strong light; and pick out with metal tweezers all knots, hairs, and dirt. This supervision is called *burling.* In large factories a room is set aside for the purpose; but it is sometimes done at the cottagers' houses, or, during the summer months, in the open air on walls or hedges.

TEAZLING.

The next process is *teazling,* by which the loose fibres of the wool are raised to the surface, so as to form, when properly cut or sheared, that beautiful pile or nap, which is so much admired in superfine cloths. This operation is performed by means of the prickly flower heads of the teazle, a species of thistle (*Dipsacus fullonum*), which is cultivated in the clothing counties for the purpose.* It is a biennial plant, and is sown in drills on strong land; it is thinned out by the hoe, and kept clear from weeds during the first year; in the second year it ought to be kept clear of weeds, although the same attention is not generally paid to hoeing as during the first. When the heads are ripe they are cut and dried for sale. There is some difficulty in drying them on account

* The Wild Teazle (*Dipsacus sylvestris*) is regarded by some botanists as a variety of the Clothier's Teazle.

of the care required to keep the heads uninjured. The cultivation of this plant requires so much attention, and the crop is so uncertain, that few manufacturers grow their own teazles. A continuance of damp weather will cause the heads of the plant to decay before they are ripe, rendering them totally unfit for the manufacturer. In Yorkshire the average

THE TEAZLE. *(Dipsacus fullonum.)*

price of a pack of teazles containing 13,500 large heads, in the proportion of six large to four small heads, varies from *5l.* to *7l.*; but in times of scarcity the price has been as high as *22l.* the pack. In abundant years the pack has been sold as low as *3l.*

Cloth was formerly teazled by hand; for which purpose a number of the heads were fixed in a small wooden frame, having cross handles eight or ten inches long, forming an instrument not unlike a curry-comb. The cloth to be teazled was hung upon two horizontal rails fastened to the ceiling. It was first damped, and then the men worked three times

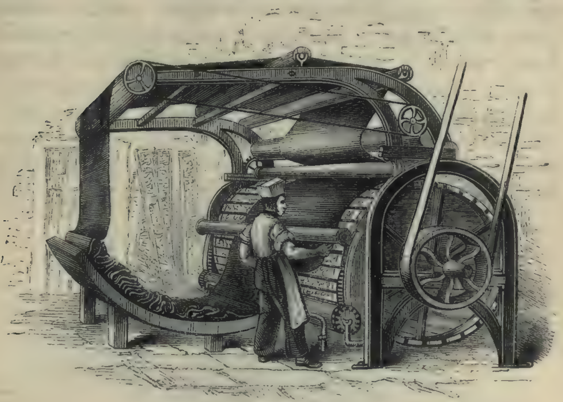
over its surface, first in the direction of the warp, and then in that of the weft, so as to raise the loose fibres from the felt, and to prepare it for shearing. When the heads became choked up with wool, they were cleared out by children, with small steel combs; but when the moisture had softened the points, it was necessary to dry the heads.

The high price of teazles, and the large number required in the manufacture (from two to three thousand being used on a piece of cloth forty yards long), have led to attempts to supersede the teazle by the introduction of wire brushes, or metallic teazle-cards, but they do but rudely imitate the action of the natural teazle, in which each head is composed of a great number of flowers separated from each other by long scales, at the end of which is a fine hook, the part so valuable to the manufacturer. These hooks are strong enough to overcome a slight impediment, but are sufficiently yielding to give way and break when they become fixed in a knot which they cannot disentangle. Metallic teazle-cards, on the contrary, instead of yielding, tear out the fibres, and injure the surface of the cloth.

The great improvement in teazling has been by the introduction of machinery. In the *gig-mill*, as it is called, the teazles are arranged in long frames attached to a hollow drum, or cylinder, and the cloth being guided by a number of rollers, is moved in a direction contrary to that of the cylinder, by which means its surface is exposed to the operation of the teazles. By the rapid revolution of the cylinder, and the slower motion of the cloth in a contrary direction, the loose fibres of the wool are brought to the surface. The long frames can be easily removed from the cylinder, and when the teazles become clogged with wool, they are removed and cleaned.

There are various forms of gig-mill, but the only

essential difference between them consists in the method of arranging the rollers, so as to bring a



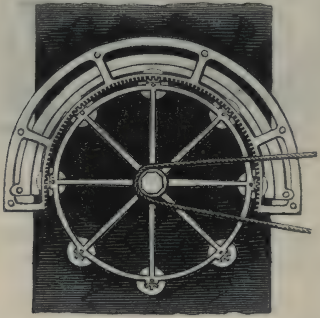
GIG-MILL FOR TEAZLING CLOTH.

greater or less extent of surface of the cloth in contact with the cylinder.

SHEARING.

As the filaments drawn forth by teazling are of very unequal lengths, they must be shorn to make them level, and this must be done with different degrees of closeness, according to the quality of the stuff, and the appearance it is desired to have. Like most of the other operations of manufactures, this was formerly done by hand,—a large pair of shears being employed for the purpose, requiring considerable dexterity on the part of the workmen. The first improvement was to work these shears by machinery — a circumstance which led to serious riots in the West of England at the commencement of the present century. The folly of these disturbances it is not necessary to point out. Machinery was successful, and continued to be improved in various ways. One ingenious contrivance consists

of a fixed semicircular rack, within or behind which is a cutting edge, called a *ledger-blade,* and a large revolving wheel, armed with eight small cutting discs, which, being in contact with the ledger-blade, form, when in motion, a series of delicate cutting shears. Each cutting disc has a toothed pinion working in the semicircular rack, which, as the large wheel revolves, gives to the cutting discs an independent rotatory motion in addition to their revolution with the large wheel. In the diagram the cloth is

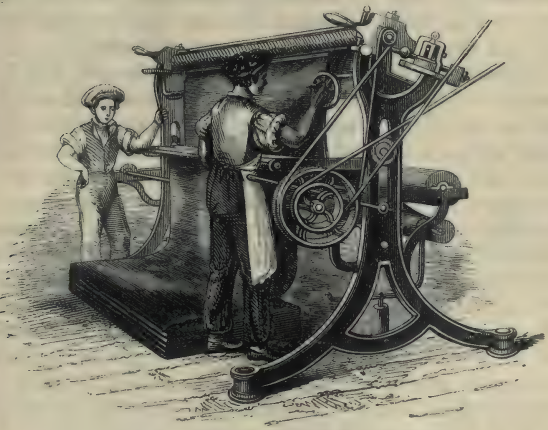


represented by the shaded part over which the machine travels; or the machine may be stationary while the cloth is moved beneath it.

The other machine in use consists of an iron cylinder, round which is a spiral cutting blade. The cylinder being made to revolve with great rapidity, the blade cuts the pile of the cloth immediately in contact beneath it, the cloth being stretched and guided by rollers. A machine of this kind is called a *perpetual.*

A single operation of raising and shearing is not sufficient to give its beautiful surface to superfine cloth. The cloth is therefore teazled a second time, deeper than the first; that is, the cloth is made to press with greater force against the teazles than in the first raising; it is then sheared a second time. By

alternately repeating these processes as often as may be required, the cloth at length assumes the appearance desired. In the West of England the first raising is called *roughing*, in which process the cloth



BROAD-PERPETUAL, FOR SHEARING CLOTH.

is worked with the teazles both ways. After being sheared it is teazled in one direction only, which is called *mozing*. It is then cut and teazled several times.

Both teazling and shearing are delicate operations: if badly done the cloth is weakened, and otherwise injured; but if well done, not only is the appearance of the fabric improved, but it acquires strength and durability; for the pile or nap is a species of fur which protects the cloth from friction and moisture.

ROLLER-BOILING.

Within the last few years a process has been introduced which greatly improves the lustre of the surface of the cloth, and prevents it from becoming spotted by rain. This process consists in winding

the cloth tightly upon a roller, and immersing it in water heated to 170° or 180° for twenty-four hours, after which it is once more stretched on the tenters and dried. This process is called *roller-boiling* or *patenting.* But as the long-continued action of hot water was found in some cases to weaken the fibre of the wool, and to change some colours, it is now customary to alternate the process with cold and hot water. For this purpose, the cloth is wound upon a drum, which rests upon a horizontal axis, half in and half out of a tank of cold water. Steam is admitted into the trough until the water is raised to the temperature of 170°. In the mean time a slow rotatory motion is given to the drum, the cloth becomes uniformly heated throughout, and by being passed in succession through the hot water and the cold air for the space of eight hours, the cloth gets a smooth soft face, and the texture is not injured. The hot water is then withdrawn, and its place supplied by cold water, in which the cloth is turned for the space of twenty-four hours, which will perfectly fix the lustre which the hot water has imparted to the face of the cloth, and leave the pile or nap in a soft silky state. This improvement is said to have been invented by Mr. Wilkins, of Tiverton, and perfected by Mr. Hirst, of Leeds.

BRUSHING, &c.

When the cloth is dry it is removed to the brushing-machine; which is a series of brushes affixed to a cylinder. In passing through this machine, the cloth is slightly damped by being exposed to steam which escapes in minute jets from a copper box extending the whole length of the brushing-machine. For the purpose of brushing, a number of pieces are stitched together at the ends so as to form an endless web.

The cloth is once more carefully examined before a strong light, and is *picked, fine-drawn,* and *marked.* The picking (which is similar in its object to burling)

is to remove all blemishes which may appear on the surface, and to cover over with the point of a pen, dipped in ink or dye-stuff, any spots which may have escaped the action of the dye. Fine-drawing is to close any minute hole or break in the fabric, by introducing, by means of a needle, sound yarns in place of defective ones; and the marking is the working in, with white or yellow silk, a word or mark indicating the quality and number of the piece, such as, *Saxony*, *extra superfine*, and so on.

PRESSING.

The pile being once more brushed, the cloth is regularly folded and subjected to hydraulic pressure. Between each fold is placed a polished pressing-board to prevent the surfaces from coming in contact; and between each piece of cloth (many pieces being pressed at the same time) iron plates are inserted. If the cloth is to be hot-pressed, three hot iron plates are inserted between the folds at the end of every twenty yards. Thin sheets of iron, not heated, are also inserted above and below the hot plates for the purpose of moderating the heat. The folded pieces are piled up in the press, and subjected to very severe pressure, till the plates are cold. The cloth is then taken out and folded again, so that the creases of former folds may come opposite the flat faces of the pressing-boards, and be removed at the second pressure.

Hot-pressing gives a satiny lustre and smoothness to the face of the cloth, which, however, is apt to become spotted and disfigured by rain, an effect which is not produced on cloth which has been *patented*. Therefore, in finishing superfine cloths, a very slight pressure is given to them, and the iron plates are moderately warmed.

The cloth is lastly made up for the market in *pieces* or *bales*, and into *ends* or *half-pieces*.

STATISTICS OF THE WOOLLEN TRADE.

The methods of carrying on the woollen trade differ in some respects in different counties, but they may all, perhaps, be referred to two systems, namely, the *factory system* and the *domestic system*. In the former, the master clothier procures foreign wool from the importer, and wool of home growth from the wool-stapler, and works it up into cloth in a large factory, employing for the purpose a number of operatives, consisting of men, women, and children, who have no property except their labour in the material upon which they are employed.

In the domestic system, the one originally adopted in this country, the manufacture is conducted by small masters, each of whom farms a few acres of land. The master, his wife, and children, occupy themselves alternately with the manufacture of woollen cloth, and the cultivation of their land. These domestic clothiers formerly made the wool into undressed cloth at their own houses; but of late years *public mills* have been established for the purpose in the clothing villages: these mills are a joint stock undertaking, each clothier subscribing 50*l.* or 100*l.* In the early part of the present century, when the factory system, with its powerful and extensive mechanical resources, was becoming generally adopted in the woollen manufacture, the domestic clothiers were under considerable alarm for the safety of their trade. A Parliamentary Committee, appointed to inquire into their case, reported that "the two systems, instead of rivalling, are mutual aids to each other; each supplying the other's defects, and promoting the other's prosperity." Experience seems to have confirmed this conclusion: the number of small manufacturers, and the quantity of cloth produced

by them, have both increased; but as the number of factories, and the quantity of cloth made in them, have increased still more rapidly, the small manufacturers now form a less proportion of the trade.

With respect to the value of the woollen trade, and the number of persons employed, Mr. M'Culloch has formed the following estimate. There are about 150,000,000 lbs. of wool worked up yearly: the value of this is taken at about 7,500,000*l.*: the value of the manufactured goods being taken at three times that of the raw wool, gives an annual amount of 22,500,000*l.* This valuation is made up in the following manner:—

Raw material	£7,500,000
Oil, soap, dye-stuffs, &c. . . .	1,600,000
Interest, profit, &c.	4,650,000
Wages	8,750,000
	£22,500,000

Dividing the amount of wages at the average rate of 26*l.* a-year to each operative, gives 336,538; which Mr. M'Culloch thinks may be taken as the number of persons employed in the woollen manufacture of this country.

Mr. Chapman, one of the Assistant Hand-loom Commissioners, by taking the number of persons *supported* by the woollen manufacture, arrives at a larger result. He estimates that, in 1831, the number of *families* engaged in the manufacture were as follows:—

In the West Riding of Yorkshire . .	85,096
In the West of England	20,851
In Norfolk and Kendal	17,570
In the Hosiery district	20,464
In other places	20,000
	163,981

Then taking the average number of persons in a family at 5⅓, he arrives at the aggregate of 874,565 persons directly supported by the woollen manufac-

ture. He also supposes that, by the year 1841, this number must have increased to 226,298 families, or 1,218,424 individuals. He supposes that the average earnings of each family is 17*s.* 6*d.* per week, which amounts to 10,296,559*l.*; and allowing for the increase in the other items since Mr. M'Culloch's estimate was made, he states the annual value of the woollen manufacture in this country thus:—

Value of wool employed . . .	£10,000,000
Oil, dye-stuffs, soap, &c. . . .	1,500,000
Wages	10,296,559
Wear and tear, profit . . .	4,359,311
	£26,155,870

The quantities and declared value of British woollen and worsted manufactures exported in 1820, 1830, 1840, and 1845, were as follows:—

	1820.	1830.	1840.	1845.	
Cloths of all sorts .	288,228	388,269	215,746	307,791	Pieces.
Napped coatings .	59,644	22,377	16,094	4,773	Pieces.
Kerseymeres . .	78,944	34,714	27,122	24,673	Pieces.
Baizes	37,183	49,164	36,044	23,583	Pieces.
Stuffs	828,824	1,252,512	1,718,617	2,212,906	Pieces.
Flannels	2,567,496	1,613,099	1,613,477	2,405,311	Yards.
Blanketing . . .	1,288,109	2,176,391	2,162,653	2,479,478	Yards.
Carpeting . . .	525,990	672,869	758,639	1,006,970	Yards.
Woollens mixed with cottons . . .	407,716	1,099,518	3,628,874	23,831,017	Yards.
Worsted hosiery .	59,390	111,146	96,946	174,061	Dozen pair.
Sundries	£39,313	£54,038	£164,034	£178,995	Value.
Declared value .	£5,507,758	£4,728,666	£5,327,853	£7,693,118	

This table does not include the exports of British sheep and lambs' wool, and woollen and worsted yarns, during the same period. They were as follows:—

	1820.	1830.	1840.	1845.
Wool . . .	35,242	2,951,000	4,810,387	9,059,448 lbs.
Spun-yarn .	11,081	1,108,023	3,796,644	9,405,928 lbs.

In the Parliamentary documents for 1845, the exports of British woollen manufactures (exclusive of wool and yarn) are entered for forty-five different

parts of the world; by which it appears, that our best customer is the United States of America, to which woollen manufactured articles were sent in that year to the amount of 1,763,174*l.*: the Hanseatic Towns are entered at 981,504*l.*: the British North American colonies at 671,998*l.*; China at 539,218*l.*; Holland at 460,122*l.*

Halls, for the sale of cloth, are established at Leeds, Halifax, Huddersfield, Bradford, and other places. A notice of the Coloured-cloth Hall at Leeds, visited by the writer, will probably be a sufficient description of the management of these buildings. There are two cloth-halls at Leeds: the

INTERIOR OF CLOTH HALL, LEEDS.

Coloured-cloth Hall, built in 1758, and the White-cloth Hall, built in 1775. The cloth-market was formerly held in an open street. The Coloured-cloth Hall is a plain building, occupying three sides of a large square, divided into eight compartments, which are called streets: these are, King-street, Queen-street, 'Change-alley, Mary's-lane, Prince of

Wales's-street, Cheapside, Commercial-street, Union-street, and New-street. Each street contains two rows of stands facing each other: each stand projects from the wall 11 or 12 feet; but it measures only 22 inches in front: it is inscribed with the name of the clothier to whom it belongs. No one can occupy a stand unless he has served a regular apprenticeship to the clothing business. Each stand, which is the absolute freehold property of the holder, cost originally about 3*l.*; and the value has been as much as eight or ten times that amount; but, since the extension of the factory system, a good deal of cloth produced in the woollen district is sold without passing through the halls, which have, consequently, lost much of their importance, and the stands do not now exceed their original value. The markets for the sale of coloured cloths are held on Tuesdays and Saturdays; on which days only are the merchants permitted to make their purchases in the halls. The time of sale commences, by the ringing of a bell, at nine o'clock in summer, and half-an-hour later in the winter half of the year from October to March. At the end of an hour the bell is rung again, to warn the buyers and sellers that the market is about to close; and in another twenty minutes the bell is rung for the third time; after which, a fine of 5*s.* is imposed on every buyer. The White-cloth Hall, situated in another part of the city, is opened immediately afterwards, and is subject to similar regulations. The cloth is brought to the halls in the undressed state; the purchasers, who are the proprietors of what are called *finishing-shops*, conduct the various finishing processes described in the present treatise. The goods produced in the West of England, and in Norfolk, are not sold in cloth-halls, but at public fairs or markets, or to the agents sent round by the drapers.

In this notice of the woollen and worsted manufacture, it might be expected that some details should

be given of the modes of manufacture of the various descriptions of goods in which wool is employed; but it may be stated that such goods as blankets, flannels, baize, stuffs, merinos, mousseline-de-laines or wool muslins, bombazets, tammies, shalloons, says, moreens, calimancoes, camlets, lustrings, and a number of others, are produced by some of the means already described in the treatises on the Manufacture of Woollen and Worsted Yarns, and of Woven Goods. Many divisions and subdivisions of the manufacture differ more in their results than in the means by which those results are attained. The mixture of woollen with worsted yarns, or either of them with cotton or silk, together with various methods of dyeing and fancy weaving, leads to an almost endless variety of woven fabrics. Thus to give a few examples:—*Kerseymere* is a fulled twilled fabric; *Serges* are also twilled, but the warp is worsted and the weft woollen; *Blankets*, and many varieties of plain coarse cloth, are made of very soft yarn, afterwards worked up into a kind of pile by milling; *Bombazeen* is a mixture of worsted and silk, twilled; *Poplin* is a similar mixture produced by plain weaving; *Stuff* is entirely worsted; *Merino* is a fine woollen twill; *Saxonies* and *Orleans* are made of woollen mixed with cotton yarn: *Cashmere* ought properly to be made of the wool of the Cashmere goat; but most of the fabrics named *Cashmeres* are made of sheep's wool; *Challis* is produced from a silk warp and a woollen weft, and is usually printed; *Mousseline-de-laine* was, as its name implies, originally all wool; but it is now commonly mixed with cotton, and printed; *Norwich Crape* is comprised of wool and silk; *Crêpe-de-Lyon* of worsted and silk. The fabrics called *Waistcoatings* are exceedingly numerous.

The principal seats of the woollen manufacture * are the West Riding of Yorkshire, and the counties

* The writer's information on this subject is obtained chiefly from M'Culloch's "Statistical Account of the British Empire."

of Gloucester, Wilts, and Somerset. The manufacturing district of the West Riding of Yorkshire is, with the exception of that of Lancashire, by far the most important of any in the kingdom. It extends from north to south about forty, its mean breadth being about twenty miles, comprising an area of nearly eight hundred square miles, and including the important towns of Leeds, Bradford, Halifax, Huddersfield, and Wakefield. The greater part of the *cloth* produced in this district is in the neighbourhood of Leeds, Wakefield, Huddersfield, and Saddleworth,—Leeds being the grand mart for *coloured* (or *mixed cloths*, as they are called, being wholly made of dyed wool,) and *white broad cloths*. *Flannels* and *baizes* are manufactured in and near Halifax, and also cloth used by the army. The *blanket* and *flushing* line lies between Leeds and Huddersfield. *Worsted* spinning is extensively carried on at Bradford; *stuffs* are made in its vicinity, and also in Halifax and Leeds. *Narrow cloths* are made in and near Huddersfield. Saddleworth furnishes broad cloths and *kerseymeres*. Wakefield is celebrated for the skill of its cloth dyers. In the neighbourhood of Batley and Dewsbury are the *shoddy-mills* employed in manufacturing yarn from old woollen rags and refuse goods, of which considerable quantities are imported. A little new wool is usually intermixed with the old, and the cloth answers sufficiently well for padding and such purposes.

Rochdale, in Lancashire, though not considered as forming part of the woollen district, has extensive manufactures of baizes, flannels, kerseys, and broad cloths.

In the West of England, the extent of the woollen manufacture is greatest in Gloucestershire, especially in the district called the *Bottoms*, of which Stroud may be considered as the manufacturing centre, all the surrounding valleys exhibiting ranges of houses or villages occupied by persons engaged in this business, and the banks of the Frome being thickly

set with fulling-mills. Broad cloths of various sorts are made in this district, but chiefly superfine, of Saxon, Australian, and Spanish wool; and fine narrow fancy goods are also extensively produced.

Bradford, in Wiltshire, is the centre of what is perhaps the greatest fabric of superfine cloth in England. Woollen cloth of thin texture is made at Wilton, and cloths of various qualities, but all fine, are made at Warminster, Heytesbury, and Calne. In Somersetshire, the manufacture is carried on chiefly at Tiverton and at Taunton, the latter being as celebrated for its manufacture of second cloth as Frome is for superfine. West of England cloths are commonly divided into five classes, according to their thickness: the thickest is *double-milled superfine;* the finest and thickest cloths are for the Turkey trade; *ladies' cloths* are rather thicker than these; cloths manufactured for the East and West Indies, a degree thicker; the superfine being, in point of thickness, next to the double-milled superfine. The Western woollen manufacture also extends into parts of Dorsetshire; while baize and flannels are produced at Sturminster Newton.

The county of Norfolk was long the seat of the stuff or worsted manufacture; but during the present century it has declined, chiefly, it is said, for want of coal. The greater part of the yarn now made use of in the Norwich factories is made at Bradford, in Yorkshire. Worsted yarn is also produced largely in Leicestershire, and to some extent in Warwick and other places.

Exclusive of the leading fabrics already adverted to, an immense variety of woollen goods are manufactured in various places, only a few of which can be noticed here. Baize and flannel are made at Bury, in Lancashire; baize, coarse cloth, and blankets, at Chichester, in Sussex. Salisbury produces flannel in small quantity. Blankets are made at Dewsbury, Witney, Dulverton, &c.; but with respect to Witney

it is remarked, that since the introduction of machinery, the chief part of the blankets sold at its markets are made in Glamorganshire.

The manufacture of carpets, druggets, and woollen and worsted stockings, will be noticed in a separate treatise.

The woollen manufacture of Wales is principally situated in the counties of Montgomery, Merioneth, and Denbigh. Its products consist of webs, flannels (the most important article of Welsh manufactures), stockings, socks, wigs, and gloves. In many parts of Wales almost every small farmer makes webs, and few cottages are without a loom.

The woollen manufacture of Scotland is inconsiderable. Fine cloth is produced in various parts of Aberdeenshire, and in some other counties; but coarse cloth is the staple article of Scotch manufacture. Some of the woollen spinning mills and factories at and near Aberdeen are upon a large scale.

In Ireland the woollen manufacture is in a very depressed state, owing in great measure to the unsettled state of the country.

With respect to the health of the operatives employed in woollen factories, a favourable opinion may be given. Mr. Thackrah states that slubbers and spinners are robust and healthy. Some of the other departments are less favourable; but on the whole, there does not appear to be anything in the manufacture itself which is prejudicial to health.